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AN

ESSAY

ON

COMBUSTION,

WITH A VIEW TO A

NEW ART

OF

DYING AND PAINTING.

WHEREIN

THE PHLOGISTIC AND ANTIPHLOGISTIC HYPOTHESES
ARE PROVED ERRONEOUS.

By Mrs. FULHAME.

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3548

WELLCOME
HISTORICAL
MEDICAL

ERRATA.

Preface, p. viii. l. 20, for *ere long*, read *erelong*.
P. 15, l. 5, for *particles of reduced gold were obſerved*, read *I obſerved many particles of reduced gold.*
P. 17, omit the three firſt lines.
P. 137, l. 15, for *or* read *nor*.
P. 163, l. 28, omit *and*.

PREFACE.

THE poſſibility of making cloths of gold, ſilver, and other metals, by chymical proceſſes, occurred to me in the year 1780: the project being mentioned to Doctor Fulhame, and ſome friends, was deemed improbable. However, after ſome time, I had the ſatisfaction of realizing the idea, in ſome degree, by experiment.

Animated by this ſmall ſucceſs, I have, from time to time, ever ſince, proſecuted the ſubject as far as pecuniary circumſtances would permit.

I imagined in the beginning, that a few experiments would determine the problem; but experience ſoon convinced me, that a very great number indeed were neceſſary, before ſuch an art could be brought to any tolerable degree of perfection.

A narration of the numerous experiments, which I made with this view, would far exceed the bounds, I preſcribe myſelf in this eſſay; I ſhall therefore preſent the reader only with a few, ſelecting ſuch as I judge moſt intereſting, and beſt adapted to illuſtrate the ſubject.

Though I was, after ſome conſiderable time, able to make ſmall bits of cloth of gold, and ſilver, yet I did not think them worthy of public attention; but by perſevering, I at length ſucceeded in making pieces of gold cloth, as large as my finances would admit.

Some time after this period, I found the invention was applicable to painting, and would alſo contribute to facilitate the ſtudy of geography: for I have applied it to ſome maps, the rivers of which I repreſented in ſilver, and the cities in gold. The rivers appearing, as it were, in ſilver ſtreams, have a moſt pleaſing effect on the ſight, and relieve the eye of that painful ſearch for the courſe, and origin, of rivers, the minuteſt branches of which can be ſplendidly repreſented in this way.

Notwithſtanding this further ſucceſs, I was dubious about the propriety of publiſhing this Eſſay; I therefore ſhewed ſome ſpecimens of theſe metallic ſtuffs to perſons, whom I thought qualified to judge of them: ſome approved of them very much, and were pleaſed to ſay, that the invention would make an era in the arts; others thought it a pretty conceit; and others were of opinion, that the ſtuffs had not that ſplendour, or burniſhed appearance, which could entitle them to public notice.

The latter opinion had much weight with me; for it muſt be allowed, that the ſpecimens, which I ſhewed them, had not that luſtre and poliſh, neceſſary for ſhoulder-knots, lace, ſpangles, gold muſlins, &c.; that ſome of them had a reddiſh caſt, bordering on the colour of copper, ſome a purple, mixed with gold; and that ſome of them were unequal in the die, and ſeemed ſtained; which imperfections were owing to a partial reduction of the metal in the fibres of the ſilk.

But all theſe imperfections, except the want of that burniſhed luſtre ſo neceſſary for gold lace, ſpangles, &c. I knew I could remedy; and therefore the criticiſm, as far as it relates to them, had no great influence with me.

I am in poſſeſſion of ſome pieces, one of which is about a yard in length, which have ſcarce any of theſe imperfections.

Moreover, that high poliſh of burniſhed gold, ſo neceſſary in ſpangles, lace, &c., would, in my opinion, be a great imperfection in gold ſtuffs deſigned for whole ſuits; as a perſon in ſuch a habit, would look like a gilded ſtatue.

I ſaw a piece of gold ſtuff made for the late King of Spain, which was of a purple colour, with gold wire ſhining through it, though rather obſcurely; and it was much admired: I was ſo ſtruck with its beauty, that I attempted to imitate it on a ſmall bit of white ſilk; and ſucceeded, having produced a beautiful purple colour, with gold beaming through it.

Therefore, the want of that burniſhed appearance is no objection to this art; for the paler, and cooler, to a certain degree, the colour of the gold is, the more lovely do theſe metallic cloths appear.

I made ſmall bits of gold tiffany, which looked exceedingly beautiful; the fineneſs of the thread contributing much to that effect; and, in my opinion, ſuch webs are inimitable by mechanical means.

Beſide, though I am not able to make cloths like burniſhed gold, others of greater means and abilities may; for we cannot pretend to preſcribe any limits to the perfection, at which chymiſtry, and the arts, may arrive.

However, I muſt acknowledge, that this unfavourable judgment ſuſpended my intention of publiſhing this little work, until a celebrated philoſopher happening, ſome time in October 1793, to ſee ſome of the ſame pieces, and indeed, ſome of the work, viewed the performance in a very different light.

This illuſtrious friend of ſcience not only approved of the ſpecimens ſhewn him, but offered to have a memoir on the ſubject preſented to the Royal Society: but different incidents diſſuaded me from that mode of publication, and induced me to adopt the preſent.

I now no longer heſitated about the propriety of publiſhing; for, every thing conſidered, I judged, that though this art could never be eſtabliſhed, which is by no means my opinion, yet the experiments themſelves, upon which I attempted to found it, as they are new, and ſeem to throw ſome light on the theory of combuſtion, are not unworthy the attention of Chymiſts.

Thoſe who viewed my performance with a favourable eye, were of opinion, that I ſhould dedicate this Eſſay to ſome patron of the arts; or apply for his Majeſty's Royal letters patent, in order to reimburſe the expence neceſſarily incurred in this inveſtigation, an expence ſo diſproportionate to the fortune which ſupported it, that nothing but a certain fatality, and the hope of reward, could induce me to perſevere.

As to patrons, I have heard of ſuch beings on the record of fame; but never ſaw one: on the contrary, it has been my lot to know of many, whoſe malignant breath, as far as its deadly influence can extend, never ceaſes to blaſt the unſheltered bloſſoms of ſcience.—And as for a patent, had I even the means, I ſhould perhaps never attempt it; for if we may judge of the future by the paſt, I can ſafely affirm, that ſuch an application would be vain.

Thus circumſtanced, I publiſh this Eſſay in its preſent imperfect ſtate, in order to prevent the furacious attempts of the prowling plagiary, and the inſidious pretender to chymiſtry, from arrogating to themſelves, and aſſuming my invention, in plundering ſilence: for there are thoſe, who, if they can not by chymical, never fail by ſtratagem, and mechanical means, to deprive induſtry of the fruits, and fame, of her labours.

But the Britiſh empire ſhould not forget, that ſhe owes her power and greatneſs to commerce; that ſhe is, as it were, the hive of the arts, and ſhould not, by the ſulphureous vapour of oppreſſion, and neglect, compel her bees to ſwarm for protection to foreign climes, but rather permit them to roam in their native ſoil, and allow them, in the winter of life, to ſip a little of the honey of their own induſtry.

The nation, whoſe evil genius withholds this protection, only ſounds the trumpet of emigration; and muſt ere long lament her cities deſerted, her fields brown with deſolation, and herſelf the eaſy prey, and vile drudge of ſurrounding greatneſs.

I firſt imagined, that the proper title of this performance, ſhould be, an Eſſay on the Art of making Cloths of Gold, Silver, and other Metals, by chymical proceſſes; but reflecting on the imperfect ſtate of the art, and that my experiments related not only to the reduction, but alſo to the calcination of metals, and other combuſtible bodies, I determined to entitle it, An Eſſay on Combuſtion, with a view to a new Art of Dying and Painting, which includes every thing the experiments can extend to.

As to the ſtyle, I have endeavoured to relate the experiments in a plain and ſimple manner, aiming more at perſpicuity, than elegance.

I have adopted the French Nomenclature, as the terms of it are ſo framed, as to prevent circumlocution, aſſiſt the memory, by pointing out the combination, and ſtate of the elements exiſting in each compound, as far as they are known; advantages to be found in no other Nomenclature.

However, the Engliſh reader muſt regret, that the French chymiſts have not preferred the terms *air*, and *ammonia*, to the leſs harmonious ſounds, *gas*, and *ammoniac*. I took the liberty of writing the latter *ammonia*.

I have not related my experiments in the order, in which they were made, ſenſible that ſuch a narration would be tedious, and that a ſhort extract from them would anſwer every purpoſe at preſent intended.

The experiments related I have endeavoured to arrange in ſuch a manner. as mutually to illuſtrate each other, by contraſting the ſucceſsful with thoſe, that failed, thus pointing out a general principle, which forms a chain through the whole, connects all the experiments, ſhows their points of coincidence, and diſagreement, and by this means furniſhes us with *data*, by which, I hope, the art may be improved.

This arrangement alſo facilitates the peruſal, and relieves the mind of that fatiguing attention, which muſt neceſſarily be given to an indigeſted maſs of inſulated experiments, that have no clew to connect them, but has, on the other hand, its diſadvantages; for it throws a ſameneſs on the work, incompatible with that variety which is often ſo agreeable.

My apparatus conſiſted chiefly of a few glaſs veſſels for the ſolution of metals, and the formation of ſuch elaſtic fluids, as I uſed. The cheapeſt, and the moſt ſimple of thoſe deſcribed by Dr. Prieſtley anſwered my purpoſe.

Dr. Nooth's machine for combining carbonic acid with water, is very convenient for making ſmall experiments with ſome kinds of gas; as the baſe of that machine ſerves to contain the materials, from which the gas is obtained; and the middle glaſs the cloth previouſly dipped in the metallic ſolution, on which the experiment is to be made.

The cloth may be ſuſpended in this part of the machine, by means of a thread, and a cork.

As this machine is uſeful only in experiments on a very ſmall ſcale, I ſometimes uſed tall glaſs cylinders, in which I ſuſpended the ſubject of the experiment, by means of a thread, a cork, and a bit of cement.

This cylinder I placed over a veſſel containing the materials, which produced the gas.

It is very convenient to have cylinders of different ſizes, proportioned to the ſcale, on which the experiments are to be made.

But machinery for confining elaſtic fluids is not always neceſſary; as moſt of the experiments may be performed in the open air.

It may appear preſuming to *ſome*, that I ſhould engage in purſuits of this nature, but averſe from indolence, and having much leiſure, my mind led me to this mode of amuſement, which I found entertaining, and will, I hope, be thought inoffenſive by the liberal, and the learned. But cenſure is perhaps inevitable; for ſome are ſo ignorant, that they grow ſullen and ſilent, and are chilled with horror at the ſight of any thing, that bears the ſemblance of learning, in whatever ſhape it may appear; and ſhould the *ſpectre* appear in the ſhape of *woman*, the pangs, which they ſuffer, are truly diſmal.

There are others, who ſuffer the ſame torture in a ſtill higher degree; but by virtue of an *old inſpiring tripod*, on which ignorance, ſervility, or chance, has placed them, aſſume a dictatorſhip in ſcience, and fancying their rights and prerogatives invaded, ſwell with rage, and are ſuddenly ſeized with a violent and irreſiſtible deſire of revenge, manifeſting itſelf by innuendos, nods, whiſpers, ſneers, grins, grimace, ſatanic ſmiles, and witticiſms uttered ſometimes in the acute, and ſometimes in the naſal obtuſe twang, with an affected hauteur, and contempt of the *ſpectre*;

ſhrugs, and a variety of other contortions, attending.

Sometimes the goblin, which thus agitates them, lurks latent, and nothing is perceived but hollow murmurs, portending ſtorms: ſometimes the lurking fiend darts with ſidelong fury at the devoted object, which, if unarmed, falls a victim to the griſly monſter.

But happily for human kind, the *magic tripod* drags none into its dizzy vortex, but thoſe who are radically ſtupid, and malicious, who are the beaſts of prey deſtined to hunt down unprotected genius, to ſtain the page of biography, or to rot unnoted in the grave of oblivion.

Although the ſurge of deliberate malice be unavoidable, its force is often ſpent in froth, and bubbles; for this little bark of mine has weathered out full many a ſtorm, and ſtemmed the boiſterous tide; and though the cargo be not rich, the dangers, which may hereafter be pourtrayed on *votive tablet*, may ſerve as a beacon to future mariners.

But happen what may, I hope I ſhall never experience ſuch deſertion of mind, as not to hold the helm with becoming fortitude againſt the ſtorm raiſed by ignorance, petulant arrogance, and privileged dulneſs.

However, were I not encouraged by the judgement of ſome friends, and poſſeſſed of ſpecimens, to ſhow the progreſs made in the art, I ſhould never perhaps venture to publiſh this Eſſay; as I am ſenſible, it labours under many imperfections, which inaccuracy of obſervation, and the drapery of imagination, muſt ſpread over the whole, imperfections perhaps unavoidable in ſuch a diſcuſſion.

Finding, the experiments could not be explained on any theory hitherto advanced, I was led to form an opinion different from that of M. Lavoiſier, and other great names. Perſuaded that we are not to be deterred from the inveſtigation of truth by any authority however great, and that every opinion muſt ſtand or fall by its own merits, I venture with diffidence to offer mine to the world, willing to relinquiſh it, as ſoon as a more rational appears.

November 5th, 1794.

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ERRATA.

Page 137, line 15, for *or*, read *nor*.
—— 156, —— 13, for *while*, read *white*.

INTRODUCTION.

THOUGH ſome of the phenomena of combuſtion were known from the earlieſt ages, yet no rational attempt to explain them was made till about the middle of the 17th century.

Before that period, it was ſuppoſed by alchymiſts and phyſicians, that ſulphur was the inflammable principle, on which all the phenomena of combuſtion depended.

But Beccher perceiving, that ſulphur did not exiſt in ſeveral combuſtible bodies, aſſerted it was not the principle of inflammability; which, he maintained, was a different ſubſtance, common to ſulphur and other combuſtible bodies: this principle he ſuppoſed to be of a dry nature, and called it inflammable Earth.

Stahl refined this hypotheſis by ſuppoſing the inflammable earth of Beccher to be pure fire, fixed in combuſtible bodies, and conſtituting an eſſential part of them.

According to Stahl, a combuſtible body is a compound, containing fixed fire, or *phlogiſton*; and combuſtion is the diſengagement of this phlogiſton from a fixed to a free ſtate, attended ſometimes with heat and light: when theſe phenomena ceaſe, the body becomes incombuſtible; if this calcined body be now heated with charcoal, or any other inflammable ſubſtance, capable of giving it phlogiſton, or fixed fire, it returns again to the claſs of inflammable bodies.

This hypotheſis is ſo ſimple and plauſible, that, ſince the year 1736, it was received, though differently modified, all over Europe.

The principal objections to it are, that the exiſtence of phlogiſton cannot be demonſtrated; and that it does not explain, why bodies become heavier after oxygenation, and lighter after reduction.

M. Lavoiſier diſcovering, that the increaſe of weight, which bodies acquire during combuſtion, is equal to the weight of the combuſtible ſubſtance, and that of the vital air employed, denied the exiſtence of phlogiſton, or fixed fire, in combuſtible bodies; though he grants the exiſtence of combined *caloric* in them. He ſeems then to allow the exiſtence of phlogiſton, but to have changed its name to that of *caloric*, and denied it the power of producing combuſtion.

However, after diſcovering that the increaſe of weight, which bodies acquire during combuſtion, depended on the quantity of the air abſorbed, he was led to the following beautiful hypotheſis, equally ſimple as that of Stahl; and if ever any hypotheſis deſerved the name of theory, ſurely it is that of M. Lavoiſier.

According to M. Lavoiſier, "an inflam-"mable body is nothing elſe but a body "which has the property of decompoſing "vital air, and taking the baſe from caloric "and light; that is to ſay, the oxygene, "which was united to them; and that a "body ceaſes to be combuſtible when its "affinity for the oxygene is ſatisfied, or when "it is ſaturated with that principle; but "that it becomes again combuſtible, when "the oxygene has been taken from it by "another body, which has a ſtronger affi-"nity with that principle.

"When this decompoſition of the air is "rapid, and, as it were, inſtantaneous, there "is an appearance of flame, heat, and light; "when, on the contrary, the decompoſition "is very ſlow, and quietly made, the heat "and light are ſcarcely perceptible *."

Thus all the phenomena of oxygenation, which Stahl aſcribed to the diſengagement of phlogiſton, M. Lavoiſier aſcribes to the union of oxygen with combuſtible bodies.

And, on the other hand, all the phenomena of reduction, which Stahl attributed

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* Eſſay on Phlogiſton, by M. Kirwan, a new edition, p. 21, and 16.

to the union of phlogiſton to calcined bodies, M. Lavoiſier attributes to the ſeparation of oxygen from the ſame. Combuſtion, then, according to Stahl, is the tranſition of phlogiſton from one body to another; and, according to M. Lavoiſier, 'tis nothing but the tranſition of oxygen from one ſubſtance to another.

Stahl ſuppoſed, that the heat, and light, attending combuſtion proceed from the burning body; but M. Lavoiſier ſuppoſes, that the heat, and light, proceed principally, and almoſt entirely, from the vital air.

However, this opinion of M. Lavoiſier is far from being eſtabliſhed; for Doctor Crawford has ſhown, that inflammable air contains a much greater quantity of heat, than vital air does.

It is evident, then, that the great advantage, which M. Lavoiſier's hypotheſis has over that of Stahl is, that the former ſeems to account for the increaſe and decreaſe of weight, which bodies ſuffer during calcination, and reduction.

Notwithſtanding this brilliant diſcovery, which ſeems to account, with ſuch eaſe, for the increaſe of weight, that bodies acquire during combuſtion, M. Macquer was of opinion, that M. Lavoiſier's hypotheſis was inſufficient to explode that of Stahl, and endeavoured to remove the objection urged againſt the nonexiſtence of phlogiſton, by ſuppoſing it to be light; and that in every caſe of combuſtion, light, and vital air, mutually precipitate each other: ſo that, according to M. Macquer, when a body is oxygenated, vital air unites to it, and diſengages light; and, on the other hand, when an oxygenated ſubſtance is reduced to its inflammable ſtate, light unites to it, and diſengages vital air.

M. Scheele alſo modified the hypotheſis of Stahl, by ſuppoſing that heat, light, and inflammable air, were compounds of empyreal, or vital air, and phlogiſton. Light, he thought, contained more phlogiſton than heat did; and inflammable air more than either: he farther ſuppoſed, that theſe compounds of vital air and phlogiſton were convertible into one another, by the addition, or ſubtraction, of phlogiſton; and that, when a metal was reduced by them, they were decompoſed; their phlogiſton uniting to the ſubſtance reduced.

His idea of calcination is, that metals either attract empyreal air by means of their phlogiſton, and thus form heat, or that they communicate their phlogiſton to the air, and attract heat from the fire; and that, either way, there is empyreal air in the calces, which makes the overplus of their weight[*].

The laſt modification of Stahl's hypotheſis is that of M. Kirwan, who ſuppoſes that inflammable air exiſts in a fixed, or concrete, ſtate in all combuſtible bodies, and is the true phlogiſton of the antient chymiſts; and, as it can be exhibited in the form of air, its exiſtence is no longer doubtful.

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[*] Experiments on Air and Fire. Eng. tranſ. p. 174.

M. Kirwan ſuppoſes, that, when combuſtible bodies are calcined, or changed into acids, they combine moſt commonly with fixed air, formed during the operation, by the union of their phlogiſton to vital air; and ſometimes to other ſubſtances, and water, which is either abſorbed *in ſpecie*, or formed by the union of their phlogiſton to vital air, during calcination.

He ſuppoſes, that ſome of theſe are reſtored to their combuſtible ſtate by the decompoſition of their fixed air; ſome partly by the decompoſition of their fixed air, and partly by its expulſion, and that of the other foreign bodies, they had abſorbed; and laſtly, that ſome recover their combuſtibility by the expulſion of water, and others poſſibly by its decompoſition in high degrees of heat. In all theſe reductions he ſuppoſes a ſimultaneous reunion of theſe bodies to phlogiſton, or the inflammable principle*.

Though M. Kirwan's hypotheſis ſeems to account for the increaſe of weight, which bodies acquire during combuſtion, yet he has not proved the exiſtence of inflammable air, in a concrete ſtate, in all combuſtible bodies; nor has he ſhown, that fixed air is a compound of inflammable, and vital air; neither has he proved, that fixed air is the acidifying principle.

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* Eſſay on Phlogiſton, a new edition, p. 38—166.

All theſe objections have been made, with great juſtice, to his hypotheſis, by the antiphlogiſtians; who alſo object, that M. Kirwan's account of calcination, and reduction, is complex, and repugnant to the ſimplicity of nature; "for," ſays M. De Fourcroy, "as "the author had admitted three general ſpe- "cies of calcination, it was neceſſary, that "he ſhould, likewiſe, admit three kinds of "reduction *."

This criticiſm is very juſt; but it will appear, that the antiphlogiſtic account of calcination, and reduction, is no leſs complex, erroneous, and repugnant to the ſimplicity of nature: for when we conſider the various ſources, whence they derive the oxygen, which oxygenates bodies; and the long liſt of metallic reducers, which they ſuppoſe; it muſt be allowed, that if ſimplicity be a recommendation, their hypotheſis is deſtitute of that advantage.

Thus, according to M. Lavoiſier, the oxygen, which oxygenates combuſtible bodies, is ſometimes derived from vital air; ſometimes from atmoſpheric air; ſometimes from acids; ſometimes from water; and ſometimes from metallic oxids, &c.

On the other hand, the catalogue of ſub-

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* Eſſay on Phlogiſton, p. 207.

ſtances, which reduce bodies to their combuſtible ſtate, is no leſs numerous.

"Heat," ſays M. De Fourcroy, "ſeparates "oxygene from ſome; one metal takes it "from another; hydrogene, or inflamma-"ble gas, takes it from moſt metals; and "carbone perhaps from all*."

To this liſt, may be added phoſphorus, ſulphur, and compounds of theſe with hydrogen; alſo light and the electric fluid, &c., as will appear in the ſequel.

But, I ſhall endeavour to ſhow, that the hydrogen of water is the only ſubſtance, that reſtores oxygenated bodies to their combuſtible ſtate; and that water is the only ſource of the oxygen, which oxygenates combuſtible bodies.

Want of ſimplicity is not the only defect in Mr. Lavoiſier's hypotheſis: for he ſuppoſes, that the increaſe of weight, which bodies acquire during combuſtion, depends on the abſorption of the oxygenous principle alone.

Thus, when a bit of phoſphorus, ſulphur, or charcoal, is burnt in vital air; the increaſe of weight, which theſe bodies acquire, he attributes entirely to oxygen, or the baſe of vital air.

Theſe combuſtions he explains, by ſuppoſing, that the phoſphorus, ſulphur, and charcoal, decompoſe oxygen gas, by abſorbing its baſe from caloric, and light, which are ſet free.

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* Eſſay on Phlogiſton, p. 205.

"There is," ſays M. Lavoiſier, "a total "abſorption of vital air, or rather of the "oxygene, which forms its baſe in the com-"buſtion of phoſphorus, and the weight of "the phoſphoric acid obtained, is found to "be rigorouſly equal to the weight of the "phoſphorus, added to that of the vital air "employed in its combuſtion. The ſame "agreement of weights is obſerved in the "combuſtion of inflammable gas and vital "air, in the combuſtion of charcoal*," &c. His idea of the calcination of metals is the ſame.

"We do not," ſays M. Lavoiſier, "affirm "that vital air combines with metals to "form metallic calces, becauſe this manner "of enunciating would not be ſufficiently "accurate: but we ſay, when a metal "is heated to a certain temperature, and "when its particles are ſeparated from each "other to a certain diſtance by heat, and "their attraction to each other is ſufficiently "diminiſhed, it becomes capable of decom-"poſing vital air, from which it ſeizes the "baſe, namely oxygene, and ſets the other "principle, namely caloric, at liberty.

"This explanation of what paſſes during "the calcination is not an hypotheſis, but "the reſult of facts. It is upwards of twelve

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* Eſſay on Phlogiſton, p. 14.

“ years, ſince the proofs have been laid by
“ one of us, before the eyes of the academy,
“ and have been verified by a numerous
“ commiſſion. It was then eſtabliſhed, that
“ when the calcination of metals is effected
“ beneath an inverted glaſs veſſel, or in
“ cloſed veſſels containing known quantities
“ of air, the air itſelf is decompoſed, and
“ the weight of the metal becomes augmented
“ by a quantity accurately equal to that
“ of the air abſorbed. It has ſince been found,
“ that when the operation was performed in
“ very pure vital air, the whole might be
“ abſorbed.”

“ No ſuppoſition enters into theſe explanations;
“ the whole is proved by weight
“ and meaſure*.”

Hence it is evident, that M. Lavoiſier confounds oxygen with oxygen gas; and conſiders the latter as a compound of oxygen, light, and caloric.

But ſince the dryeſt oxygen gas contains a large proportion of water, as Dr. Prieſtley and M. Kirwan have ſhown †; and ſince the whole of the gas, except the caloric, and light, is abſorbed, it neceſſarily follows, that the increaſe of weight, which bodies acquire during combuſtion, depends not only on the oxygen, but alſo on the water, contained in vital air.

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[*] Eſſay on Phlogiſton, p. 13—15.

[†] *Ibid.* p. 25. and Philo. Tranſ. Vol. 78. p. 314.

Therefore oxids are compounds of combuſtible bodies united to oxygen, and water.

Another great objection to M. Lavoiſier's hypotheſis, is, that he ſuppoſes both oxygenation, and reduction, effected by a ſingle affinity.

Thus, according to him, when iron reduces a ſulphate of copper, the iron does nothing more, than ſeparate the oxygen from the copper, by its ſuperior attraction for that principle.

From this view of combuſtion, grounded on the moſt accurate experiments in chymiſtry, it is manifeſt, that the antiphlogiſtic hypotheſis does not account fully for the increaſe of weight, which bodies acquire during combuſtion; and conſequently, that it cannot be admitted as a juſt theory.

CHAPTER I.

REDUCTION OF METALS

BY

HYDROGEN GAS.

AS Hydrogen, or the baſe of inflammable air, ſeems to act an important part in the following experiments, and is, according to ſome chymiſts, pure phlogiſton itſelf; I have therefore aſſigned the firſt chapter in this eſſay to hydrogen gas, this being the moſt ſimple form, in which hydrogen has hitherto been obtained.

But I had not the means of procuring this gas free of carbone, and other impurities, that it diſſolves and elevates during its formation; or of excluding atmoſpheric air, which circumſtances, I am ſenſible, muſt, in ſome meaſure, influence the reſult; as it cannot be ſuppoſed, that theſe extraneous bodies would remain inactive during the proceſs of reduction. However, as ſuch exactneſs is not in the power of every experimenter, I was under a neceſſity of uſing hydrogen gas, with the diſadvantages here mentioned.

Though moſt of the experiments in this eſſay were made on a variety of white and coloured ſilks, I ſhall relate only thoſe made on the former, as it exhibits the changes produced more diſtinctly, and contains leſs foreign matter to modify the reſult of experiment; and, for brevity's ſake, I ſhall uſe the term *ſilk*, by which *white ſilk* is always deſigned.

EXP. I. GOLD.

I poured a quantity of ſulphuric ether on a ſolution of gold in nitro-muriatic acid, and, by this means, obtained a ſolution of gold in ether, which I ſeparated from the acid.

In this ethereal ſolution of gold, I dipped a piece of ſilk, after it was taken out, and the ether evaporated, it was ſuſpended in a tall glaſs cylinder, placed over a veſſel, containing a mixture of diluted ſulphuric acid, and iron filings.

The ſilk thus expoſed to a rapid current of hydrogen gas acquired, after ſome time, a purple colour, and a large ſpangle of gold, of an irregular figure, appeared on the upper end of the ſilk, and looked very brilliant.

The ſilk was kept expoſed to the gas about four months, and frequently obſerved, but no other remarkable change was perceived, except that the purple colour became more intenſe: the experiment was now diſcontinued; and on taking out the ſilk, and examining it in the light of the ſun, particles of reduced gold were obſerved; but they were very ſmall, and by no means ſo brilliant, as that, which firſt appeared.

During the experiment, freſh quantities of materials for ſupplying hydrogen gas were occaſionally added.

From the brilliant ſpangle of reduced gold obſerved in this experiment, I concluded, that there was a ſufficient quantity of the metal in the fibres of the ſilk, could it be reduced.

This ſpot of reduced gold was very permanent, and adhered firmly to the ſilk.

EXP. 2. GOLD.

In order to determine, whether a ſolution of gold in ether, or one in water, were beſt adapted to the object of theſe experiments; I evaporated to dryneſs a ſolution of gold in nitro-muriatic acid, and diſſolved the ſalt in diſtilled water: in this ſolution, I immerſed a piece of ſilk, which, after it was dried in the air, was ſuſpended in a glaſs cylinder, like the former piece, and expoſed to the action of hydrogen gas about two months.

The ſilk after ſome time aſſumed a purple colour, and five or ſix ſpecks of reduced gold, of the ſize of pin heads, and one much larger, were obſerved. Examining the ſilk in the ſun-beams, I perceived the whole of it ſpangled with minute particles of reduced gold.

After many experiments with theſe two ſolutions of gold, I was led to conclude, that the ſolution in water anſwered beſt.

EXP. 3. SILVER.

Having diſſolved ſome pure ſilver in diluted nitric acid, and evaporated ſome of the water by a gentle heat, I placed it in the dark to cryſtallize. The cryſtals were ſeparated from the ſolution, and diſſolved in diſtilled water; to one meaſure of this ſolution, which was ſaturated with the nitrate of ſilver, ten or twelve meaſures of diſtilled water were added.

In this diluted ſolution, a piece of ſilk was dipped; after it was taken out, it was dried at the fire: the ſilk dried in this manner, retained its white colour; whereas, were it dried gradually in the air; and eſpecially, were the light conſiderable, its white colour would be changed to a reddiſh brown, more or leſs intenſe, according to the quantity of light preſent.

Some kinds of ſilk, on being immerſed in a ſolution of nitrate of ſilver, have ſome of their threads immediately coloured brown: but I often got white ſilk, which would retain a ſolution of nitrate of ſilver, have ſome of their threads immediately coloured brown; but I often got white ſilk, which would retain its pure white colour, if dried at the fire, or in the dark.

The piece of ſilk dried, as above, was ſuſpended in the middle glaſs of Dr. Nooth's machine; and into the lower glaſs were introduced a diluted ſolution of ſulphuric acid, and ſome ſmall iron nails.

The machine was now placed in a dark cloſet, to exclude the action of light; after ſome time, the ſilk, thus expoſed to hydrogen gas, put on a light brown colour, which gradually became deeper, until it was changed to a diſagreeable black, with ſome mixture of brown: then very ſmall particles of reduced ſilver began to appear, which increaſed by degrees, in number, and brightneſs.

The experiment was continued four months; after which time, the ſilk was taken out of the machine: it had a gray metallic appearance, intermixed with a conſiderable tinge of brown.

This experiment was repeated on another piece of ſilk, every circumſtance being the ſame, except that a quantity of water was put in the middle glaſs of the machine, over which the ſilk was ſuſpended; the intention of interpoſing the water in this experiment was to purify the gas.

The appearances were much the ſame, as in the laſt experiment; except that the ſilk became black ſooner; and that ſome ſpangles of the ſilver were larger, and better reduced.

The ſpecks of reduced ſilver were permanent, and adhered firmly to the ſilk.

EXP. 4. LEAD.

In a ſolution of acetite of lead in diſtilled water I dipped a piece of ſilk, and dried it in the air; it was then ſuſpended over a quantity of water in Dr. Nooth's machine, and expoſed to hydrogen gas about three months.

The appearances were much the ſame as in the laſt experiment, except that the ſilk was not ſo black: the particles of reduced lead reſembled ſilver.

Similar experiments were made in this machine on bits of ſilk imbued with a ſolution of nitro-muriate of gold in water; but the appearances being much the ſame as thoſe mentioned in the firſt and ſecond experiments, it is unneceſſary to repeat them here.

It is much eaſier to imagine, than expreſs my anxiety, to diſcover the cauſe of the brilliant ſpecks of reduced gold and ſilver, with which the pieces of ſilk in theſe experiments were ſometimes ſpangled; concluding, that were the cauſe aſcertained, it would be a conſiderable ſtep towards accompliſhing the object in view.

But many and diverſified were the experiments I made before the circumſtance, on which theſe ſpangles depended, was perceived.

At length, I found it depended on the preſence of moiſture; and that the ſpangles of reduced metal were owing to ſmall drops of water carried up by the elaſtic fluid, and depoſited on the ſilk.

The experiments, which led to this concluſion, ſhall be related in their proper places. I ſhall now proceed to recite the remainder of the experiments in this eſſay, conformable to the plan laid down in the preface, premiſing an occurrence obſerved in the courſe of them.

I ſometimes found, that the production of hydrogen gas from a mixture of acid, water, and iron nails, would unexpectedly ſtop, which induced me to add more acid; this not ſucceeding, I added more water; but ſtill no gas was formed: the proportions of acid and water were varied without effect. Thinking the mixture of acid and water unfit for the purpoſe, I poured it off, and repeatedly waſhed and agitated the nails with more water, which was alſo poured off; but happening inadvertently to add ſome of the mixture of acid and water, which I had before poured off as unfit for uſe, I was ſurpriſed to find the gas produced with great rapidity.

Reflecting on the cauſe of this odd circumſtance, I concluded that it depended on a cruſt of ſuperoxygenated iron, formed on the ſurface of the nails, which defended them from the action of the water and acid, and that this cruſt was removed by the agitation and waſhing, which enabled the diluted acid to act again on the iron.

EXP. 5. GOLD.

I immerſed a bit of ſilk in a ſolution of nitro-muriate of gold in diſtilled water, and dried it in the air; it was then placed over a cylindrical glaſs veſſel, containing a mixture of diluted ſulphuric acid and iron nails, for about half an hour; but no reduction of the metal could be obſerved.

I dipped another bit of ſilk in the ſame ſolution of gold, and expoſed it, while wet, to the ſame current of hydrogen gas, and inſtantly ſigns of reduction appeared; for the yellow colour, which the ſolution imparts to ſilk, began to change to a green, and very ſoon a film of reduced gold glittered on the ſurface oppoſed to the gas: ſhortly after, a beautiful blue ſpot, fringed with orange and purple, was formed on the middle of the ſilk. During the experiment, which laſted about half an hour, the ſilk was kept conſtantly wet with diſtilled water.

When experiments are made with this preparation of gold, it is neceſſary to evaporate the ſolution to dryneſs, before the ſalt be diſſolved in the water; as an exceſs of acid prevents the reduction in a great meaſure. Solutions of gold in theſe experiments do not admit of being ſo largely diluted, as ſolutions of ſilver, and other metals do.

EXP. 6. SILVER.

I immerſed a piece of ſilk in a ſolution of nitrate of ſilver, and dried it in a dark place; it was then expoſed to a current of hydrogen gas about twenty minutes; but no reduced ſilver appeared, the only change obſervable was a brown ſtain.

I immerſed another bit of the ſame ſilk in the ſame ſolution of ſilver, and having expoſed it, while wet, to a ſtream of hydrogen gas, I ſoon obſerved evident ſigns of reduction; the white colour of the ſilk was changed to a brown, which became gradually more intenſe; and the ſurface of the ſilk, oppoſed to the gas, was coated with reduced ſilver: various colours, as blue, purple, red, orange, and yellow, attended the reduction. Theſe colours often change, and are ſucceeded by others in the progreſs of the reduction. The threads of the ſilk look like ſilver wire, tarniſhed in ſome parts, but of great luſtre in others.

The ſilk was kept wet with diſtilled water during the experiment. When the ſilk happened to be too much wetted, the under ſurface oppoſed to the gas was often covered with ſcales of a dull blue colour: theſe, after the ſilk dries, may be bruſhed off, and another coat of reduced ſilver, which adheres firmly, but has no conſiderable brightneſs, is left behind.

Theſe experiments on the reduction of gold, and ſilver, were often repeated with nearly the ſame reſult.

EXP. 7. SILVER.

Thinking ſome other preparation of ſilver might anſwer better than a nitrate, I precipitated ſome of the latter with a ſolution of muriate of ſoda, and poured the whole on a filter; the precipitate was well waſhed with diſtilled water, and diſſolved in ammonia. In this ſolution I immerſed a piece of ſilk, and dried it in the air; and having expoſed it to the action of hydrogen gas, I could perceive no ſigns of reduction, except a faint brown colour.

I dipped another bit of ſilk in the ſame ſolution of ſilver, and in order to determine if water had the power of promoting the reduction of the ſilver in this preparation, as it had in the former experiments, I expoſed the ſilk, while wet, to the ſame current of hydrogen gas; and in a few ſeconds the metallic luſtre was evident on the ſurface oppoſed to the current. After ſome little time, a blue ſpeck and a faint trace of yellow appeared, but ſoon vaniſhed.

This preparation of ſilver does not ſtain white ſilk ſo much as a nitrate does; the reduced ſilver was indeed very brilliant, but ſoon grew dull, and diſappeared; a brown ſtain only remaining; ſo that it ſeems rather inferior to nitrate of ſilver, which alſo, after reduction, tarniſhes, grows dull, and often diſappears; but ſometimes part of it remains permanently reduced.

EXP. 8. PLATINA.

With much difficulty I procured a ſmall quantity of the ore of platina, and diſſolved it in nitro-muriatic acid. The ſolution was evaporated to dryneſs, and the ſalt was then diſſolved in diſtilled water.

A bit of ſilk was dipped in part of this ſolution, and dried in the air; it was then expoſed to a briſk current of hydrogen gas about twenty minutes, but no ſigns of reduction appeared.

Another bit of ſilk was immerſed in the ſolution of platina, and expoſed, while wet, to the ſame current of hydrogen gas; in five or ſix minutes the platina was reduced, exhibiting a livid white metallic appearance on the ſurface of the ſilk oppoſed to the current. No colours attended the reduction. This ſolution imparts a yellowiſh brown colour to ſilk.

After ſome time, the whole of the metallic luſtre diſappeared, in proportion as the ſilk became dry.

The ſolution of platina requires more time, and a ſtronger current of hydrogen gas for its reduction, than ſolutions of ſilver and gold do.

EXP. 9. MERCURY.

I immerſed a bit of ſilk in a ſolution of oxygenated muriate of mercury in diſtilled water, and dried it in the air: it was then expoſed to a ſtream of hydrogen gas; but underwent no viſible change.

I dipped another bit of ſilk in the ſame ſolution of mercury, and expoſed it, while wet, to the ſame current of gas; the metal was ſoon reduced in a beautiful manner, and reſembled ſilver.

The reduction began ſuddenly, with ſcarce any appearance of previous ſtain; ſome very faint, but at the ſame time tranſparent colours attended it: the moſt remarkable of theſe were a light orange, with a fringe of blue, and a yellow verging on a faint green. Theſe colours ſoon diſappeared.

After the ſilk was turned, I obſerved, that its texture was, in ſome parts, concealed by a thin film, which, as the reduction proceeded, was perceived to dart along the threads of the ſilk, gilding them in a beautiful manner, and exhibiting the texture very diſtinctly.

After ſome time, the mercury ſeemed to diſappear, ſo as to render it doubtful whether any of it remained in the ſilk; but ſhaking it in the ſunbeams, I perceived bright atoms fly off; and rubbing the ſilk on a bit of blue paper, I obſerved ſhining metallic particles, which ſeemed to have loſt their affinity of aggregation, for they did not unite.

One remarkable difference between this preparation of mercury and nitrate of ſilver, is, that no black or brown ſtain preceded, attended, or followed, the reduction of the mercury.

Mr. Scheele reduced a pruſſiate of mercury, diſſolved in water, by adding iron filings and a ſmall quantity of ſulphuric acid to the ſolution *.

EXP. 10. COPPER.

A piece of ſilk was immerſed in a ſolution of ſulphate of copper, then taken out, and dried, and expoſed for a conſiderable time to a briſk current of hydrogen gas; but no ſigns of reduction could be perceived.

Another bit of ſilk was dipped in the ſame ſolution of copper, and expoſed, while wet, to the ſame rapid current of hydrogen gas; the appearances were the following.

After a minute, or two, the ſilk aſſumed a faint brown colour, and, on the ſurface oppoſed to the gas, a white metallic pellicle appeared, which vaniſhed in proportion as the ſilk became dry: wetting the ſilk again, I perceived a ſimilar pellicle appear, which alſo vaniſhed, as ſoon as the ſilk dried. If the ſilk be kept conſtantly wet, the brown

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* Scheele, p. 162, French tranſlation.

colour becomes much more intenſe, attended with a very ſlight tinge of red. The margins of the ſilk projecting beyond the verge of the glaſs cylinder, and therefore not expoſed to the current of the gas, retained the blue colour, which the ſolution imparts.

In ſome of theſe white metallic pellicles there appeared a faint brown inclining to yellow, which reflected the light, though obſcurely.

After the ſilk dried, nothing remained, but a brown ſtain.

EXP. II. LEAD.

A piece of ſilk was immerſed in a ſolution of acetite of lead in diſtilled water; it was then dried, and expoſed for ſome time to a ſtream of hydrogen gas; but underwent no perceptible change.

Another bit of ſilk was dipped in the ſame ſolution of lead, and expoſed, while wet, to the ſame current of hydrogen gas; in a ſecond, or two, the ſurface of the ſilk, oppoſed to the current, was coated with reduced lead, which looked like ſilver.

The reduction was accompanied with a brown ſtain, but by no means ſo intenſe as that, which attends the reduction of nitrate of ſilver.

The other ſide of the ſilk was oppoſed to the current of hydrogen gas, and ſoon acquired a metallic coat of the ſame brilliant appearance;

appearance, exhibiting the texture of the ſilk, in a very ſtriking manner.

It is remarkable, that lead exhibits no colour, but a light brown, during its reduction; whereas gold, ſilver, and mercury, diſplay a great variety of colours, eſpecially the two former.

After ſome time the lead reduced in this manner loſes its metallic ſplendour conſiderably; and that in proportion as the ſilk dries.

EXP. 12. TIN.

I diſſolved ſome cryſtals of muriate of tin in diſtilled water; dipped a bit of ſilk in the ſolution; and dried it in the air: it was then expoſed to a ſtream of hydrogen gas a conſiderable time; but no change, or appearance of reduction, could be obſerved.

Another bit of ſilk was immerſed in the ſame ſolution of tin, and expoſed, while wet, to the ſame current of gas; after ſome little time, the reduction commenced, attended with a great variety of beautiful colours; as red, yellow, orange, green, and blue, variouſly intermixed.

The reduced tin diſappears along with theſe colours, as the ſilk dries; nothing remaining but a feuille-morte colour.

The ſame ſolution of tin was alſo reduced by hydrogen gas, obtained from tin, and the muriatic acid.

Theſe experiments do not ſucceed well with muriate of tin containing an exceſs of acid.

EXP. 13. ARSENIC.

A muriate of arſenic, which was prepared by digeſting white oxid of arſenic in muriatic acid, and continuing the heat, till moſt of the acid evaporated, and left behind a ſoft maſs of the conſiſtence of tar, was diſſolved in diſtilled water.

In this ſolution a bit of ſilk was immerſed, and dried in the air: it was expoſed to a briſk ſtream of hydrogen gas, obtained from zinc, and muriatic acid; but no reduction took place.

Another bit of ſilk was dipped in the ſame ſolution, and expoſed, while wet, to the ſame current of hydrogen gas; and inſtantly, the ſurface of the ſilk, oppoſed to the gas, was covered with a bright coat of reduced arſenic, accompanied with a yellow ſtain. In a ſhort time the metallic luſtre vaniſhed; and nothing remained but the yellow ſtain.

M. Pelletier reſtored the acid of arſenic to its metallic ſtate, by paſſing hygrogen gas through a ſolution of that acid, in twice its weight of water *.

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* Roz. Journ. Feb. 1782.

EXP. 14. BISMUTH.

A bit of ſilk, which was immerſed in a ſolution of nitrate of biſmuth in diſtilled water, and expoſed dry to hydrogen gas, obtained from zinc, and muriatic acid, underwent no viſible change.

Another bit of ſilk was dipped in the ſame ſolution of biſmuth, and placed over a languid ſtream of hydrogen gas; the biſmuth was ſoon reſtored to its metallic form, on the ſurface of the ſilk oppoſed to the elaſtic fluid. The reduction was attended with a reddiſh brown ſtain, intermixed with a tinge of violet.

EXP. 15. ANTIMONY.

A bit of ſilk was immerſed in a ſolution of tartarite of antimony in diſtilled water; and dried in the air. It was then expoſed to hydrogen gas, obtained from zinc, and muriatic acid; but ſuffered no viſible alteration.

Another bit of ſilk, which was dipped in the ſame ſolution of antimony, was expoſed wet to a weak ſtream of the gas; and, in a ſhort time, the metallic luſtre appeared, accompanied by a light yellow colour.

EXP. 16. IRON.

A bit of ſilk, which was immerſed in a largely diluted ſolution of ſulphate of iron, and dried in the air, was expoſed to a ſtrong current of hydrogen gas, obtained from iron nails, and diluted ſulphuric acid; but no viſible change was produced on the ſilk.

Another bit of ſilk was dipped in the ſame ſolution of iron, and placed wet over the ſame ſtream of hydrogen gas; but no reduced iron could be perceived. The ſilk was then immerſed in a glaſs of clear water, and transferred a very minute metallic film to the ſurface of that fluid.

This experiment was repeated with a rapid current of hydrogen gas, obtained from zinc, and muriatic acid; and, in about a minute, ſmall films of reduced iron were viſible on the ſurface of the ſilk, oppoſed to the gas.

The ſilk was then immerged in water, and transferred to its ſurface a large metallic pellicle; parts of which were very brilliant; but other parts were dull, and much more imperfectly reduced.

EXP. 17. ZINC.

A bit of ſilk, which was dipped in a muriate of zinc, largely diluted with water, and dried in the air, was expoſed to a rapid current of hydrogen gas, obtained from zinc, and muriatic acid; but ſuffered no viſible alteration.

Another piece of ſilk was immerſed in the ſame ſolution of zinc, and expoſed, while wet, to the ſame rapid current of hydrogen gas: in about half a minute, the metal was reduced in a very evident manner, on part of the ſilk. The ſilk was then dipped in a glaſs of clear water, and transferred a bright metallic film to its ſurface.

As theſe reductions of iron, and zinc, by hydrogen, are contrary to M. Lavoiſier's table of the affinities of the oxygenous principle; I began to ſuſpect, that the films, which were ſo evident, both on the ſilk, and the water, might be abraded, or torn from the zinc, by the muriatic acid; and elevated, and depoſited on the ſilk by the gas.

In order to remove this doubt, I dipped a bit of the ſame ſilk in diſtilled water; and expoſed it, while wet, to the ſame current of hydrogen gas, but nothing metallic could be ſeen on the ſilk; nor did it when immerſed in water transfer a film, or the ſmalleſt appearance of a metal, to the ſurface of that fluid: and, therefore, there can be no doubt of the reality of theſe reductions.

Dr. Prieſtley reſtored iron, and lead, to their metallic ſtate, by heating their oxids with a burning glaſs in hydrogen gas.

Theſe experiments point out an error in M. Bergman's table of elective attractions in the humid way; for he aſſigned the laſt place in that table to phlogiſton, which he conſidered as the baſe of inflammable air; becauſe he was unacquainted with any metallic reductions effected by hydrogen in the humid way *.

Having found, that water promoted, and accelerated, theſe reductions in a very remarkable manner; I was curious to know, if alcohol, and ether, would produce the ſame effect. With this view, I evaporated a ſolution of gold in nitro-muriatic acid to dryneſs; when the veſſel cooled, ſome alcohol was poured on to diſſolve the ſalt; and immediately the veſſel containing the ſalt, became ſo hot, that it could be ſcarcely endured by the hand; and diffuſed a fragrant ſmell, like that of ether, which, no doubt, was a ſpecies of that fluid.

EXP. 18. GOLD.

In this ſolution of gold in alcohol, a bit of ſilk was dipped, and expoſed to a ſtream of hydrogen gas, obtained from diluted ſulphuric acid, and iron nails; and kept wet with alcohol: in about two minutes, the ſilk began to aſſume a brown colour, and white metallic films appeared on ſome parts of the ſurface oppoſed to the gas; ſome of theſe diſappeared in a ſhort time; and were ſucceeded by a few very ſmall ſpangles of the proper colour of gold. Theſe alſo ſoon vaniſhed; and nothing remained but a diſgree-

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* ElectiveAttractions, Engliſh Tranſlation, p. 87.

able brown ſtain, intermixed with ſpecks of a dull blue.

I ſometimes found, on repeating this experiment, that no yellow films or ſpangles appeared; and am perſuaded, that their appearance, and that of the white pellicles alſo, depends on the preſence of water, contained in the alcohol, or the gas, and depoſited on the ſilk.

EXP. 19. GOLD.

A bit of ſilk was immerſed in a ſolution of gold in ether, and expoſed to a ſtream of hydrogen gas, and kept wet with ether. The ſilk underwent no alteration for a few minutes; at length, it began to aſſume a faint brown colour, but no white, or yellow films appeared.

If this experiment be continued till the ſilks collects a ſufficient quantity of water from the gas, ſome films will appear.

EXP. 20. SILVER.

I procured ſome nitrate of ſilver, which had been fuſed in order to expell as much of its water as poſſible; and diſſolved it in alcohol. I immerſed a bit of ſilk in this ſolution, and expoſed it to a ſtream of hydrogen gas, and kept it wet with alcohol: in a few ſeconds, the ſilk aſſumed a brown colour, which gradually became more intenſe: but no reduced ſilver appeared for ſeveral minutes;

nutes; at length, a few metallic films appeared on part of the ſurface oppoſed to the gas.

Exp. 21. MERCURY.

A bit of ſilk was dipped in a ſolution of oxygenated muriate of mercury, and dried; it was then expoſed to hydrogen gas about ten or fifteen minutes, and kept conſtantly wet with alcohol. The ſilk, during the firſt minutes, ſuffered no perceptible alteration: at length, a few ſmall films were viſible on the ſide of the ſilk oppoſed to the current.

Exp. 22. LEAD.

A bit of ſilk, which was immerſed in a ſolution of acetite of lead, and dried, was expoſed about fifteen minutes to a ſtream of the gas; and kept conſtantly wet with alcohol; but ſuffered no viſible change; except that a very minute film was reduced on one of its margins, which did not project beyond the verge of the glaſs veſſel on which it was placed.

When we compare theſe experiments with thoſe, in which water was uſed, to wet the ſilk, 'tis evident, that alcohol, and ether, do not promote the reduction of metals, as water does; and that the few films, which appear, when the ſilk is kept wet with ether or alcohol, depend entirely on water collected from the gas, or depoſited by them on the ſilk during their evaporation.

In order to compare the effects of hydrogen gas, obtained from water, iron nails, and muriatic acid, with that, procured from the ſame materials, by means of the ſulphuric; I made ſome experiments on gold, ſilver, mercury, and lead, in the ſame manner, as the preceding; and the principal difference was, that the colours produced in all the pieces of ſilk, except that, which was dipped in acetite of lead, were much brighter, and more beautiful, than any produced, when the ſulphuric acid was uſed.

The reduction of the lead was accompanied with its uſual brown colour.

On the upper ſurface of a bit of ſilk, which was dipped in a ſolution of gold, a green colour inſtantly appeared; and ſoon changed to a deep olive, in proportion as the reduction advanced: now examining the under ſurface, I ſaw it coated with a bright film of reduced gold, in the middle of which a blue ſpangle, mixed with purple, ſoon began to appear: I then moiſtened the upper ſurface of the ſilk with water; and in a few ſeconds, it alſo was coated with reduced gold.

The blue on the other ſide of the ſilk became much more intenſe: the piece was now turned; and on each colour I let fall a drop of water: the drop on the blue had a blue film, the drop on the purple, had a purple film, and the drop on the yellow, a film of reduced gold.

After ſome time, theſe drops of water evaporated,

porated, and the films came again in contact with the ſilk: ſome parts of which were left bare, as generally happens, when too much water is applied.

On the under ſurface of a bit of ſilk, which was immerſed in a ſolution of nitrate of ſilver in water, a coat of reduced metal was formed, with various colours, as green, blue, orange, and yellow, the beauty and brightneſs of which were remarkable.

In ſome time a muriate of ſilver is formed in the fibres of the ſilk, which on expoſure to light becomes of a bluiſh black colour: but the whole of the ſilver does not undergo this change; for part of it remains in its metallic ſtate. The colours remain a conſiderable time, if the ſilk be removed from the gas before this muriate is formed.

Hence it appears, that hydrogen gas ſhould not be prepared with an acid, which forms an inſoluble compound with the metal to be reduced.

I alſo found, that hydrogen gas produces different effects not only according to the difference of the acid, but alſo according to the difference of the metal employed to obtain it: for this gas procured from zinc or tin, and muriatic acid, did not reſtore gold to its proper metallic luſtre; but formed on the ſilk, a white metalline coat like ſilver.

The experiments related in this chapter indicate the following concluſions.

1. Hydrogen is capable of reducing the

metals in the ordinary temperature of the atmoſphere.

2. Water promotes, and accelerates, theſe reductions, in a very remarkable manner.

3. Ether, and alcohol, do not promote theſe reductions, without the aid of water.

4. A variety of colours accompanies theſe reductions, ſimilar to what appears, during the calcination of metals by heat and air; and depends on the ſame cauſe: viz. the quantity of oxygen combined with the metal.

Theſe colours have not been obſerved hitherto; nor indeed could they; as the metals were reduced in cloſe veſſels, and in high degrees of heat.

5. Theſe reductions often diſappear.

This is commonly owing to an imperfect, and partial reduction of the metal: for the acid, and water, remaining in that part of the metallic ſolution, not reduced, recalcines theſe delicate films: ſometimes the diſappearance of the metallic luſtre depends on the nature of the metal itſelf: thus arſenic, lead, ſilver, &c., ſuffer ſome degree of calcination by water and atmoſpheric air.

Meſſrs. Bergman and Keir relate inſtances, in which ſilver after being precipitated in its metallic ſtate, was recalcined, and diſappeared.

I firſt imagined, that water promoted theſe reductions by minutely dividing the particles of the metallic ſalt, and by condenſing the gas, and bringing its hydrogen, and the metallic

tallic oxid, within the ſphere of attraction; the hydrogen either uniting to the metallic earth and reducing it, as the Phlogiſtians ſuppoſe; or uniting with, and ſeparating the oxygen of the metal, and thus reſtoring it to the metallic form, as the Antiphlogiſtians maintain.

But it is evident from the experiments related, that water does not promote theſe reductions ſolely, by minutely dividing the particles of the metallic ſalt: for were this the caſe; ether, and alcohol, ſhould promote the reduction of the metallic ſalts, which they diſſolve, ſince they divide their particles, as minutely as water can.

Since then metallic ſolutions in ether, and alcohol, cannot be reduced by hydrogen gas; it follows that the above ſuppoſition concerning the mode of agency of water does not account for rhe reduction of metals in this way.

And indeed were it true that hydrogen condenſed by water reduced metals in the manner above mentioned, it would follow, that the reduction was effected by a ſingle affinity, which cannot be admitted; 1ſt. becauſe the exiſtence of a ſingle affinity in ſuch caſes has not been proved; 2dly, becauſe a double affinity always takes place in preference to a ſingle affinity, which is demonſtrated by the following facts, tranſcribed from the works of Mr. Kirwan.

" If a ſolution of ſilver in the nitrous acid
" be thrown into a mixed ſolution of fixed

" alkali and common ſalt, the ſilver will be " precipitated by the marine acid of the " common ſalt, and not by the free alkali, " contained in the liquor: for a luna cornea " is found *."

" I repeated the experiment with a ſolu- " tion of lead, and alſo of mercury in the " nitrous acid, and the reſult was ſimilar: " horn lead and marine ſalt of mercury were " formed †."

In theſe experiments of Meſſrs. Monnet and Kirwan, 'tis evident that a double affinity takes place in preference to a ſingle one: for the nitrous acid of theſe different nitrates unites with the alkali of the common ſalt, while the muriatic acid of the latter ſeizes the ſilver, mercury, and lead, of the nitrates, and forms muriates of ſilver, mercury, and lead: the free alkali remaining paſſive in the mixture.

M. Lavoiſier ſays, " There exiſts only in " nature, as far as we can obſerve them, " caſes of double affinity, often triple, and " others perhaps ſtill more complicated ‡."

Now as water does not promote theſe reductions merely by diſſolving, and minutely dividing, the particles of the metallic ſalts, and condenſing the hydrogen gas; and ſince a double affinity takes place in preference to

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* M. Monnet Diſſolution de Metaux, p. 159.

† Phil. Tranſ. Vol. 73. An. 1783.

‡ Eſſay on Phlogiſton, a new Edit. by M. Kirwan, p. 46.

a ſingle affinity; it is obvious that the water muſt be decompoſed in theſe reductions in the following manner.

The hydrogen of the gas unites to the oxygen of the water, while the hydrogen of the latter unites in its naſcent ſtate to the oxygen of the metal, reduces it, and forms water.

Thus what could never be effected by a ſingle, is readily performed by a double affinity.

Hence it follows, that the hydrogen of the gas is oxygenated by the oxygen of the water, while the metal is, at the ſame time, reſtored to its combuſtible ſtate. It alſo follows, that the quantity of water formed is double that decompoſed.

CHAPTER II.

Reduction of Metals by Phoſphorus.

THE next ſubſtance, of whoſe effects in reducing metals in the fibres of ſilk, I ſhall treat, is Phoſphorus, one of the moſt inflammable ſubſtances, we are acquainted with.

I was for ſome time at a loſs, how to apply it to this purpoſe; but learning from a note of Mr. Lewis, that it is ſoluble in ether; I diſſolved a ſmall quantity of it in that fluid, which can be eaſily effected, if the ether be good. The ſolution is conſiderably promoted by a gentle heat, as that of the hand, and may be made in a ſmall phial, which ſhould be nearly filled with the ether, and accurately corked: a common cork is preferable, for this purpoſe, to a glaſs ſtopper; and a ſingle grain of phoſphorus is ſufficient for a great number of experiments.

I ſometimes applied a much greater degree of heat than the above, by placing the phial in hot ſand, preſſing on the cork at the ſame time with my finger, to prevent its being forced out by the expanſion of the ether, part of which is converted into an elaſtic fluid, and holds ſome phoſphorus in ſolution: the ether ſoon begins to boil; the phoſphorus melts; and a ſtrong ſolution is obtained in a few minutes by ſhaking the phial. If the ſolution be removed to a cool place, it frequently depoſits cryſtals.

This manner of preparing the ſolution is attended with ſome danger; for ſhould the phial burſt, or the cork be extruded, the contents will be thrown out with conſiderable force, and that part of the phoſphorus not diſſolved by the ether burn with great violence.

The only objection to this preparation of phoſphorus is the ether, which muſt neceſſarily modify the reſult, and prevent that ſimplicity ſo deſirable in experiment.

But, after ſome obſervation, it was perceived, that the ether flies off, and leaves the phoſphorus pure, and minutely divided in the fibres of the ſilk: the ether, from its great volatility, firſt evaporates, and, at the ſame time, produces a very conſiderable degree of cold, which effectually prevents the evaporation, and combuſtion, of the phoſphorus.

After the ether evaporates; the cold ceaſes, and the combuſtion of the phoſphorus commences, attended with white fumes, which continue till the whole is conſumed, if no other power intervene.

Hence it is evident, that this preparation of phoſphorus has a ſimplicity, and elegance, not always to be obtained.

It has alſo another great advantage in experiments of this kind; for it does not change, in the ſmalleſt degree, the white colour of ſilk, during its ſlow combuſtion, which is not attended with heat ſufficient to affect the moſt delicate colour. This property of not affecting the colour of the ſilk renders obſervation, and experiment, more accurate; as whatever change ſupervenes, muſt depend either on the metallic ſolution itſelf, or on the action of the phoſphorus on the ſame. But this advantage is confined to a certain range of the thermometer; for if the heat be increaſed to about 86° of Fahrenheit, and the ſilk be dry, the phoſphorus is apt to ſet fire to it.

EXP. I. GOLD.

I immerſed a bit of ſilk in a ſolution of gold in ether, and after the ether evaporated, dropped on it ſome of the ſolution of phoſphorus, which diffuſed itſelf through the ſilk, like a drop of oil, and formed a circumſcribed ſpot, whoſe limits, as the ether evaporated, aſſumed a brown colour, which ſoon diffuſed itſelf equally over every part, to which the ſolution of phoſphorus was applied; but the parts of the ſilk, to which the latter did not reach, retained the yellow colour, which the ſolution of gold gave them.

The ſilk viewed by tranſmitted light preſented the ſame colours, except that the limits of the brown appeared more intenſe, and ſeemed to border on a faint purple.

Examining the ſilk next day, I found, that the whole of the brown ſtain acquired a faint ſhade of purple, which was moſt evident on the margins of the ſtain.

EXP. 2. GOLD.

I dipped a bit of ſilk in the ſolution of gold in ether, and after it was well dried, half of it was wetted with diſtilled water; the other half remaining dry: the ſolution of phoſphorus was applied to both the moiſt and dry parts of the ſilk: inſtantly the part wetted with the water began to acquire a purple colour; and, ſoon after, the metallic ſplendour of the gold appeared; but that part, which was kept dry, acquired only a brown ſtain, ſimilar to that deſcribed in the preceding experiment.

I repeated theſe experiments many times, and always found, that the gold was reduced only in proportion to the water applied.

Finding water promoted the reduction of gold by phoſphorus, I began to form various conjectures about its mode of action: I firſt ſuppoſed, it acted by holding the particles of the ſalt minutely divided, thus diminiſhing their attraction of coheſion, and conſequently increaſing their chymical attraction.

The truth of this ſuppoſition might, I thought, be decided by uſing ether, and alcohol,

cohol, inſtead of water, to wet the ſilk, avoiding aqueous moiſture, as much as poſſible; accordingly, I made the following experiments, which were frequently repeated with nearly the ſame reſult.

EXP. 3. GOLD.

A piece of ſilk was immerſed in the ſolution of phoſphorus; as ſoon as the ether evaporated, and the phoſphorus began to fume, an ethereal ſolution of gold was dropped on the ſilk, which immediately got a brown colour; the piece was kept conſtantly wet with ether; in ſome time a purple tinge appeared on parts of the ſilk; and, ſhortly after, ſmall films of reduced gold appeared: the ſilk was now remarkably wet, and ſeemed to have a great power of collecting water; this, I ſuppoſed, was partly attracted from the air by the ſalt, and phoſphorous acid formed during the combuſtion, which has a powerful attraction for water; and partly depoſited in the ſilk by the ether during its evaporation.

In order to determine if the ether during its evaporation depoſited water in the ſilk, I kept a bit of ſilk wet with ether for a few minutes, and found, that, after the evaporation ceaſed, the ſilk was moiſt: but this humidity was not ſo great, as that obſerved in the ſilk, to which the ethereal ſolutions of phoſphorus, and gold, were applied.

Another bit of ſilk was dipped in the ethereal ſolution of gold, and after the ether evaporated, the ſolution of phoſphorus was applied: a brown colour was produced; the ſilk was kept wet with ether, and, in a ſhort time, a purple tinge appeared on parts of it; but chiefly at the margin of the ſtain, which gradually diffuſed itſelf over the whole.

The only difference between this and the preceding experiment on gold is the order, in which the ſolution of gold, and phoſphorus, were applied to the ſilk; but there is a conſiderable difference in the reſult; for in this the brown and purple colours were formed much more ſlowly, and no particles of reduced gold appeared till after a much longer time.

EXP. 4. GOLD.

A piece of ſilk was immerſed in the ſolution of phoſphorus, and when the white fumes began to riſe, a ſolution of gold in alcohol was applied to the ſilk, which was kept wet with alcohol; a brown tinge, which ſoon changed to a purple, appeared on different parts; and, in a little time after, a very ſmall film of reduced gold was viſible on a part of the margin.

In another experiment, conducted in the ſame manner, the reduction was more evident.

The ſolution of gold uſed in this experiment was very rich; and had a great attraction for water; for bits of ſilk tinged with it, could not be dried without difficulty; and after they were removed to a cool place, they very ſoon became moiſt again. This is more or leſs the caſe with ſolutions of gold in general.

EXP. 5. GOLD.

A bit of ſilk was dipped in a ſolution of gold in alcohol, and dried; then ſome of the ſolution of phoſphorus was poured on the ſilk; a brown, and then a purple colour, appeared; and in ſome parts a ſmall portion of the gold was reduced: the reduction was very obſcure; but became gradually more evident, in proportion as it attracted water from the air. The ſilk was occaſionally wetted with alcohol.

This experiment was repeated, with this difference, that the ſilk was not kept wet with alcohol; and no reduced gold could be perceived.

EXP. 6. GOLD.

In order to exclude water more effectually, a ſmall phial was carefully dried by placing it in hot ſand, and then corked, to prevent the acceſs of moiſture from the air; when the phial cooled, it was nearly filled with ether, and a ſmall bit of phoſphorus dropped into it; it was then corked, and replaced on the hot ſand; the phoſphorus ſoon melted, and a ſtrong ſolution was obtained by ſhaking the phial.

Into this ſolution a ſmall bit of ſilk, which was dipped in a rich ſolution of gold, and carefully dried, was introduced: the ſilk immediately got a brown tinge; but not a particle of reduced gold could be perceived. The ſolution in a ſhort time became turbid, and depoſited a brown powder. The colour of theprecipitate was exactly the ſame, as that which the ſilk acquired. The experiment was continued about three months, and carefully obſerved; but no other change could be perceived: at the end of this time the ſilk was taken out of the phial; and the ſolution of phoſphorus was found capable of reducing gold and ſilver by the aid of water.

Exp. 7. Gold.

In order to contraſt the effects of water with thoſe of ether, and alcohol, more fully, a piece of ſilk was immerſed in a ſolution of nitro-muriate of gold in water, and dried in the air about twelve hours; during which time the yellow tinge, the ſolution of gold gave the ſilk, remained unchanged: the ſolution of phoſphorus was then applied; a brown ſtain appeared; the ether ſoon evaporated; the phoſphorus began to fume; and the ſilk acquired a purple colour; but not a particle of reduced gold could be perceived.

The purple tinge in this bit of ſilk was much more intenſe, and more equal, than in the pieces, in which ether and alcohol were uſed.

EXP. 8. GOLD.

I dipped a piece of ſilk in the ſolution of phoſphorus, when the ether evaporated, and the phoſphorus began to fume, a ſolution of gold in water was applied; inſtantly the ſilk was covered with a ſplendid coat of reduced gold.

Nothing can be more ſtriking than this experiment, which was repeated times without number, or demonſtrates the neceſſity of water in theſe reductions in a more convincing manner.

This piece, viewed by tranſmitted light, had a purple colour with a conſiderable tinge of blue; and the margin of the reduced gold was fringed with purple.

EXP. 9. GOLD.

Thinking that phoſphorus applied in the form of vapour through the medium of water might be more effectual than a ſolution of it in ether, I immerſed a ſmall bit of ſilk in an aqueous ſolution of gold, and ſuffered it to dry a little; it was then ſuſpended in a phial over a little water, into which a ſmall bit of phoſphorus was previouſly introduced: the phial was then corked, and placed on hot ſand: the phoſphorus began to melt, and aſcend in white vapours, which, as ſoon as they reached the lower end of the ſilk, gave it a brown tinge, ſucceeded by a purple; and the gold began to aſſume its metallic ſplendour: in a ſhort time theſe appearances were evident over the whole ſilk.

The following propoſitions are deducible from theſe experiments.

1. Water does not promote the reduction of gold merely by diſſolving, and minutely dividing, the particles of the ſalt, and thus diminiſhing their attraction of coheſion, and conſequently increaſing their chymical attraction, as I firſt ſuppoſed; for were this the caſe, ether and alcohol, which equally diſſolve, and divide, the ſalt, ſhould produce the ſame effect.

2. Ether and alcohol do not promote theſe reductions without the aid of water; for it is evident from the experiments related, that the few particles of reduced gold, which appear, when they are employed, depend entirely on the quantity of water, which they leave in the ſilk during their evaporation, and that attracted from the air by the ſolution of gold, and by the phoſphorus during its combuſtion, both of which have a ſtrong attraction for water.

3. Phoſphorus does not reduce gold by giving the metallic earth phlogiſton, as the Phlogiſtians ſuppoſe; for were this opinion true, a ſolution of gold in ether, or alcohol,

ſhould be reduced by the phoſphorus as effectually as a ſolution of gold in water is.

4. Phoſphorus does not reduce gold, by combining with, and ſeparating, the oxygen of the gold, as the Antiphlogiſtians aſſert; for were this the caſe, the particles of the phoſphorus ſo attenuated by the ether, ſhould reduce a ſolution of gold in ether, or alcohol, as well as a ſolution of gold in water, ſince the impediment oppoſed by the attraction of coheſion is equally removed in both caſes.

I ſhall conclude theſe remarks on the reduction of gold with the following experiment, which often amuſed me.

EXP. 10. GOLD.

A ſmall bit of ſilk was immerſed in a ſolution of gold in ether, and dried; then the ſolution of phoſphorus was applied, which changed the yellow colour of the ſilk to a brown: when the phoſphorus began to fume, I placed the ſilk on the palm of my hand, and breathed on it a conſiderable time; a purple tinge gradually ſucceeded the brown, and, in ſome little time after, the metallic luſtre of the gold began to appear.

The ſame experiment ſucceeds with a ſolution of gold in alcohol.

Another bit of ſilk, treated in the ſame manner, was placed over the vapour of warm water for ſome time; the ſame appearances took place, and particles of reduced gold were evident in the ſilk.

If the water, whence the vapour ariſes, be too hot; the heat retards, and ſometimes prevents, the reduction, by volatilizing the phoſphorus.

EXP. 11. SILVER.

I dipped a bit of ſilk in a ſolution of fuſed nitrate of ſilver in alcohol, and dried it in the air: then ſome of the ſolution of phoſphorus was applied, which produced a brown ſtain, whoſe margin, after a few minutes expoſure to the air, acquired a livid white appearance, cauſed by a partial and imperfect reduction of the ſilver.

This, however, would not be taken by a perſon unacquainted with experiments of this kind for reduced ſilver.

EXP. 12. SILVER.

A bit of ſilk was immerſed in the ſolution of phoſphorus; as ſoon as the ether evaporated, and the phoſphorus began to fume; a few drops of the ſolution of ſilver in alcohol were applied: immediately a black ſtain, intermixed with ſome brown, appeared: and, after ſome time, obſcure films of reduced ſilver preſented themſelves; theſe appeared on different parts of the ſtain; but were ſo minute as to be ſcarce viſible. The only difference between this and the preceding experiment is the order, in which the ſolutions were applied; but even this modifies the reſult in ſome meaſure.

That theſe imperfect reductions depended on water, depoſited in the ſilk, by the alcohol during its evaporation, or attracted from the air by the phoſphorus during its combuſtion, will appear from the following experiment.

EXP. 13. SILVER.

A ſmall phial was well dried in hot ſand, then corked, and removed to a cool place: after the phial cooled, it was nearly filled with ether, and a ſmall bit of phoſphorus, which was repeatedly waſhed in alcohol to free it from any aqueous moiſture, that might adhere to it, was introduced; the phial was then corked, and placed in hot ſand; when the phoſphorus melted, I ſhook the phial, and obtained a ſtrong ſolution.

Into this ſolution a ſmall bit of ſilk, which was dipped in a ſolution of ſilver in alcohol, and dried, was introduced: the phial was corked; the ſilk inſtantly aſſumed a brown colour; but not a particle of reduced ſilver could be ſeen, though the experiment was continued about three months; nor did the ſolution of phoſphorus become turbid, or depoſit any precipitate, as happened in ſimilar experiments on gold.

At the end of this period the ſilk was

taken out of the phial, wetted with water, and ſuſpended in a window; and, after a conſiderable time, reduced ſilver was manifeſt on different parts of the ſilk.

With the ſolution of phoſphorus, in which the ſilk ſtood during that time, I reduced gold, and ſilver, with the aſſiſtance of water.

In order to compare the effects of water with thoſe of ether and alcohol, I made the following experiments.

EXP. 14. SILVER.

I dipped a bit of ſilk in a ſolution of nitrate of ſilver in water, and dried it at the fire: the ſilk thus dried retained its white colour: the ſolution of phoſphorus was then applied, and immediately produced a brown colour, which ſoon, in proportion as the phoſphorus fumed, acquired a deeper tinge, verging on black; and ſlight ſigns of reduction appeared after a little time on the margin of the ſtain.

Another bit of ſilk, treated in the ſame manner, but dried much better, exhibited ſtill fainter ſigns of reduction: for the brown ſtain did not appear on this piece as ſoon as on the former, nor was it ſo intenſe; however, after ſome minutes expoſure to the air, the ſtain became deeper, and its margin acquired a livid white appearance, owing to a partial reduction of the ſilver.

It has been often remarked, that the reduction commences firſt on the margin of the ſtain, which the ſolution of phoſphorus, and that of the metal, produce in the ſilk: I was a long time at a loſs to account for this appearance; but the cauſe was accidentally diſcovered; for happening to ſpill a few drops of the ſolution of phoſphorus on a table, I obſerved, that, as they evaporated, watery circles were formed round the ſpaces, on which the drops fell; and, that all the parts within the circles were dry.

This explains why the reduction begins on the margin of the ſtain.

I obſerved the ſame of alcohol; for if it be dropped on a level ſurface, it leaves a watery ring behind, though not near ſo ſoon, as a ſolution of phoſphorus in ether does: this is the reaſon why alcohol ſeems to promote the reduction of ſome metals; I ſay ſeems; for it does not promote it, but in proportion to the quantity of water it contains, or attracts from the air, and depoſits in the ſilk during its evaporation.

How eſſential water is to the reduction of metals will appear from the following experiment.

EXP. 15. SILVER.

I immerſed a piece of ſilk in the ſolution of phoſphorus, and after the ether evaporated, and the phoſphorus began to fume, a ſolution of nitrate of ſilver in water was applied; inſtantly the ſilver was reſtored to its metallic ſplendour.

This experiment is very amuſing, and well calculated to ſtrike the beholder with ſurpriſe.

The reduction is ſometimes attended with ſpangles of a beautiful blue, which appear chiefly where the ſolution of ſilver is moſt abundant.

The ſolution of ſilver is commodiouſly applied by a camel hair pencil.

I alſo tried the effects of the vapour of phoſphorus on bits of ſilk dipped in a ſolution of nitrate of ſilver in water, and expoſed to the vapour, in the ſame manner as in experiment the 9th; and the ſilver was always reduced: but a ſolution of phoſphorus in ether ſeems preferable to the vapour.

A ſmall glaſs tube, reſembling a thermometer, with its bulb terminating in a ſmaller and nearly capillary tube, I found uſeful, and economic, eſpecially in experiments on gold: by immerſing the ſmaller end in the metallic ſolution, and inſpiring through the tube at the ſame time, the bulb may be filled: by this means a ſingle drop, or more, if neceſſary, may be applied to the ſilk; and, thus, a great number of experiments can be made on a ſingle grain, or a much leſs quantity, of gold, or any other metal.

This little inſtrument may be uſed alſo to apply the ſolution of phoſphorus to the ſilk;

and it was by uſing it for this purpoſe, I diſcovered, that phoſphorus has not the power of reducing ſilver without the aid of water; for blowing the ſolution of phoſphorus from the tube on bits of ſilk, which had been dipped in a ſolution of ſilver, and dried, I was ſurpriſed to find films of reduced ſilver frequently appear; whereas none appeared, when I applied the ſolution of phoſphorus in a different manner: this unexpected event often occurred, before I learned the cauſe; at length I ſuſpected, it might depend on the moiſture of the breath; and I was ſoon convinced by moiſtening the ſilk with water, that the ſuſpicion was well founded.

It is evident from theſe experiments on ſilver, that water is eſſential to the reduction of this metal by phoſphorus; and that ether, and alcohol, do not promote it.

It is alſo evident, that theſe experiments, and thoſe, made on the reduction of gold, mutually illuſtrate each other; and confirm the concluſions drawn from them.

EXP. 16. PLATINA.

I immerſed a bit of ſilk in a ſolution of nitro-muriate of platina in diſtilled water, and dried it in the air; the ſolution of phoſphorus was then applied to the ſilk; but no appearance of reduction could be perceived.

Another bit of ſilk was dipped in the ſolution of phoſphorus; when the ether evaporated,

porated, and the phoſphorus began to fume, the ſolution of platina was applied to the ſilk; and, in ſome time, delicate films of reduced platina were viſible where the water was moſt abundant. Theſe films of platina commonly diſappear; and nothing remains but a brown tinge, which, however, is more intenſe, than what the ſolution of platina alone gives the ſilk.

To ſucceed in this experiment, the ſilk ſhould be replete with phoſphorus; which is eaſily done by applying the ſolution twice or thrice, and waiting after each application, till the fumes begin to appear. It is alſo neceſſary to keep the ſilk conſtantly wet with water. Sometimes it requires from ten to twenty minutes to reduce platina in this manner.

EXP. 17. MERCURY.

I dipped a bit of ſilk in a ſolution of oxygenated muriate of mercury, and dried it in the air; then the ſolution of phoſphorus was applied; when the ether evaporated, and the phoſphorus began to fume, a yellow ſtain commenced on the margin, and gradually appeared over the whole.

To compare the effects of different degrees of moiſture, I immerſed a bit of ſilk in the ſame ſolution of mercury, and dried it carefully at the fire; the ſolution of phoſphorus was then applied; the ſilk began to fume;

but no change, except a very ſlight ring of a yellow hue, appeared. The reſt of the ſilk retained its white colour.

Another bit of ſilk was immerſed in the ſolution of phoſphorus, when the ether evaporated, and the phoſphorus began to fume, the ſame ſolution of mercury in diſtilled water was applied; and, in a few ſeconds, a bright film of reduced mercury was viſible on the margin of the part, to which the metallic ſolution was applied, and after ſome time appeared on the whole. The reduction was attended with the colours of the rainbow.

After a little time, theſe colours vaniſh, and the metallic film becomes much more obſcure, according as the ſilk dries, and is ſucceeded by a yellow ſtain.

EXP. 18. MERCURY.

A bit of ſilk was dipped in a ſolution of nitrate of mercury in diſtilled water, and dried at the fire; then the ſolution of phoſphorus was applied; and, when it began to fume, a brown ſtain commenced at the margin, which ſoon diffuſed itſelf over the whole, and gradually acquired a faint tinge of black.

Another piece of ſilk, treated in the ſame manner, but dried in the air, exhibited the ſame appearances; except that the brown tinge verged more on black.

Another bit of ſilk was immerſed in the

ſolution of phoſphorus, and when it began to fume, the ſolution of nitrate of mercury was applied; a brown colour inſtantly appeared, accompanied with a film of reduced mercury, which was moſt evident where the metallic ſolution was moſt abundant. This film ſoon diſappeared, and was ſucceeded by a black ſtain, in which, however, reduced mercury was viſible. No colours but black, and brown, appeared in this experiment.

It appears from theſe experiments on mercury, that the reduction kept pace with the quantity of water preſent.

EXP. 19. COPPER.

A piece of ſilk was immerſed in a ſolution of ſulphate of copper, and dried in the air: then a ſtrong ſolution of phoſphorus was applied; the ſilk acquired a brown colour; but no other viſible alteration occurred.

Another piece of ſilk was dipped in the ſame ſolution of copper, and dried at the fire much better than the preceding; the ſolution of phoſphorus was applied; when the ether evaporated, and the phoſphorus began to fume, a brown tinge commenced on the margin of the ſilk, and gradually diffuſed itſelf over the whole; but the ſtain was by no means ſo intenſe as that produced in the preceding piece: ſo that there can be no doubt that the difference was owing to the different degrees of moiſture in the ſilk.

After this piece remained in the air for ſome time, the brown tinge became more intenſe, a proof that it attracted water from the air. This difference in the appearances of pieces dried in the air, and at the fire, I frequently remarked.

EXP. 20. COPPER.

A ſtrong ſolution of phoſphorus was applied to a piece of ſilk, when the ether evaporated, and the phoſphorus began to fume, a ſolution of ſulphate of copper was applied; a brown ſtain was inſtantly produced, and its margins were ſoon covered with a *white* metallic film, parts of which, after ſome time, verged on the colour of copper, intermixed with purple, green, and blue. If the ſolution of phoſphorus be weak, which is always the caſe, when the ether is bad, nothing appears on the ſilk but the brown ſtain, and the *white* metallic film. As the ſilk dries moſt of theſe appearances vaniſh; but ſome of the blue tinge ſurvives; and the ſilk looks very unſeemly.

A bit of ſilk was immerſed in the ſame ſolution of copper, and expoſed to the vapour of phoſphorus, as in experiment the 9th; but no change was produced on the ſilk, except a few brown ſpots, though the heat was ſuch that the vapour filled the phial, and circulated through it: the vapour corroded a braſs pin, which was uſed to ſuſpend the ſilk in the phial. This induced me to try its effects on copper, which was corroded by it in a remarkable manner, and changed into a black ſubſtance reſembling a mixture of charcoal and oil. It appears then that phoſphorus is ill adapted to the reduction of this metal.

EXP. 21. TIN.

A bit of ſilk was immerſed in a ſolution of muriate of tin in diſtilled water, and dried in the air; the ſolution of phoſphorus was then applied to the ſilk, and though it fumed conſiderably, no change whatever could be perceived in the colour of the ſilk; nor was there the ſmalleſt appearance of reduction.

I poured ſome of the ſolution of phoſphorus on a bit of ſilk, and when it began to fume, the ſolution of tin was applied: after a few ſeconds, white metallic films appeared, firſt on the margin, and were gradually diffuſed over that part of the ſilk, to which the muriate of tin was applied: a yellow colour intermixed with red ſometimes attends the reduction. After ſome little time theſe films of reduced tin vaniſh, and ſcarcely leave a ſtain behind.

I did not ſucceed in reducing acetite of lead, muriate of arſenic, or ſulphates of iron, and zinc, in this way.

Theſe experiments on tin ſhew that water is eſſential to its reduction by phoſphorus, and give additional force to the preceding concluſions.

M. Sage diſcovered that gold, ſilver, &c. are precipitated from their ſolutions in the metallic form, by pieces of phoſphorus, which are covered at the ſame time with bright coats of gold, ſilver, &c.

To determine if water were eſſential to theſe reductions performed by M. Sage, I made the following experiments.

EXP. 22. GOLD.

Some ſolution of phoſphorus in ether was poured into a china cup, and a few drops of the ethereal ſolution of gold were added; inſtantly a brown powder was precipitated ſimilar to what appeared in experiment the 6th, but no gold in its metallic form could be perceived.

EXP. 23. GOLD.

A ſolution of nitro-muriate of gold in water was poured into a china cup, containing a ſolution of phoſphorus in ether; inſtantly the gold began to aſſume its metallic ſplendour, attended with a variety of colours, as purple, blue, and red, the beauty of which cannot be deſcribed: the quantity of the blue was gradually diminiſhed, and what remained, was diſperſed over the ſurface in ſmall films, intermixed with ſpangles of reduced gold. Moſt of the blue films were of a cira circular figure; ſome had a central ſpeck of ruby red, and were fringed with purple; ſome had a round central ſpeck of a darker blue than the ſurrounding parts: and ſome were of an irregular figure, fringed with purple, or ruby red. I often obſerved theſe blue films aſſume the real colour of gold without ſuffering any intermediate change of colour; and, I think, I obſerved the ſame of one of the largeſt ſpecks of ruby red, that appeared in this experiment. All theſe colours diſappeared, when the reduction was completed.

The variety of colours, which thoſe films aſſume, depends on the different degrees of reduction; that is to ſay, on the quantity of oxygen combined with the metal: in proportion as the metal is deprived of the oxygen, it aſſumes various colours, which often ſucceed each other in a regular order, ſhowing the different ſtages of the reduction: thus when gold is reduced; the firſt perceptible change is a green, which ſoon becomes olive; this is ſucceeded by blue, and purple; and ſometimes by a ruby red: the purple tinge is a mixture of blue, and red.

The various colours, which metals, and their calces, communicate to glaſs, and other ſubſtances, are explicable on theſe principles: and the difficulty of obtaining a ruby-coloured glaſs by gold is readily underſtood from the facility, with which that metal parts with oxygen.

EXP. 24. GOLD.

A thread was paſſed by means of a needle through a ſmall bit of phoſphorus, which was freed from any moiſture, that might adhere to it, by immerſing it for ſome time in alcohol; it was then ſuſpended by means of the thread in a ſolution of gold in ether, contained in a phial, which was carefully dried in hot ſand: in a few minutes, the ſolution became turbid, an efferveſcence commenced, and a brown precipitate was formed: according as the precipitate fell, the ſolution became clear, loſt its yellow colour; and the whole of the gold ſeemed to have been precipitated: but not a particle of reduced gold could be ſeen.

Another bit of phoſphorus was ſuſpended in the ſame manner in a ſolution of nitro-muriate of gold in water; and in a few minutes got a ſplendid coat of reduced gold.

EXP. 25. SILVER.

A few drops of a ſolution of fuſed nitrate of ſilver in alcohol were poured into a china cup containing a ſolution of phoſphorus in ether: inſtantly a black precipitate, with a tinge of brown, was formed; but no ſilver in its metallic ſtate could be perceived.

After ſome time the precipitate attracted moiſture from the air; and ſome films of reduced ſilver appeared.

The ſame experiment was made in a phial, which was corked, to exclude the moiſture of the air; and nothing, but the black precipitate, appeared.

Some of the ſame ſolution of ſilver was diluted with water, and dropped on a ſolution of phoſphorus in ether; and inſtantly films of reduced ſilver floated on the ſurface.

EXP. 26. SILVER.

A bit of phoſphorus was ſuſpended by a thread in ſome of the ſame ſolution of ſilver in alcohol, contained in a phial carefully dried: a black precipitate with a tinge of brown ſoon appeared; but no ſilver in its metallic ſtate could be obſerved; part of the precipitate adhered to the phoſphorus, and part fell to the bottom of the phial.

In another experiment made in a phial not ſufficiently dried, a few ſmall films of reduced ſilver were obſerved on the ſides of the phial; but not a particle of ſilver in its metallic form could be ſeen on the phoſphorus.

Another bit of phoſphorus was ſuſpended in a diluted ſolution of nitrate of ſilver in water: and in ſome hours, the phoſphorus was covered with reduced ſilver.

The caſe of ſilver, which covered the phoſphorus, prevented its ſpontaneous combuſtion in the air; the ſame was obſerved of the bit of phoſphorus coated with gold.

Hence it appears, that M. Sage's ſucceſs in reducing metals by phoſphorus depended on the water of the metallic ſolution.

Theſe experiments were often repeated with nearly the ſame reſult; but ſome variety often occurs, depending on various circumſtances; as the ſtrength of the metallic ſolution, and that of the phoſphorus; the quantity of water preſent, and the purity of the materials employed.

It is difficult to obtain ether, or alcohol, with the leaſt poſſible quantity of water; and equally difficult to expel all moiſture from the ſurface of glaſs; for this reaſon, the bits of phoſphorus in the experiments made with alcohol and ether were ſuſpended by threads, ſo as not to touch the ſides of the glaſs.

I ſhall conclude this chapter with a general view of the inferences, which ſeem naturally to flow from theſe experiments with phoſphorus.

1. Water is eſſential to the reduction of metals by phoſphorus; for theſe experiments ſhow that the reduction is effected only in proportion to the quantity of water preſent.

2. Phoſphorus does not reduce the metals by giving them phlogiſton.

3. Phoſphorus does not reduce the metals by uniting with, and ſeparating, their oxygen.

How then is the reduction effected? are we not to conclude, that it is effected by the decompoſition of the water, in the following manner?

The phoſphorus attracts the oxygen of the water, while the hydrogen of the latter unites, in its naſcent ſtate, with the oxygen of the metal, and effects the reduction.

Hence it follows, that the phoſphorus is oxygenated by the oxygen of the water, while the metal is reſtored to its combuſtible ſtate.

Thus what could never be effected by a ſingle, is readily performed by a double affinity; which always takes place in preference to a ſingle affinity, as the experiments of Meſſrs. Monnet, and Kirwan, mentioned in the preceding chapter, ſhow.

It is well known, that phoſphorus kept in water acquires an oxygenated cruſt, which could not happen without a decompoſition of the water: this fact ſerves to confirm the explanation here offered.

And indeed the decompoſition of water in theſe experiments muſt be granted, or it muſt be ſuppoſed, that water itſelf reduces the metals, by uniting with their earths, and conſtituting their phlogiſton; or by uniting with, and ſeparating, their oxygen; ſuppoſitions repugnant to our preſent knowledge of chymiſtry.

CHAPTER III.

Reduction of Metals by Sulphur.

THOUGH Sulphur, as far as my reading extends, has ſeldom been conſidered as a reducer of the metals, yet as it holds a diſtinguiſhed rank among combuſtible bodies, analogy led me to examine its powers in reducing and fixing the metals in the fibres of ſilk.

The vapour of ſulphur appeared to be the moſt ſimple form, in which it could be applied to this purpoſe; and may be obtained by placing a phial containing flowers of ſulphur in hot ſand: as the ſulphur melts, it aſſumes the form of vapour, which ſoon fills the phial, expels the atmoſpheric air, and bears a conſiderable heat, before it inflames; a bit of ſilk, prepared for the experiment, may be held over the vapour, as it iſſues from the phial, or immerſed in it. The neck of the phial ſhould be of a convenient ſize for this purpoſe.

But theſe experiments are more conveniently made by means of a ſulphurous match, and a glaſs funnel, in which the ſilk imbued with the metallic ſolution may be ſuſpended by a thread paſſed through it, and made faſt with a cork, which alſo ſerves to confine the vapour.

The glaſs is then placed on a table, and by moving it a little beyond the verge of the ſame, a lighted match is readily introduced, which, as ſoon as the glaſs is filled with vapour, may be withdrawn; the vapour is confined by making the glaſs glide back on the table; and thus the phenomena of the experiment can be eaſily obſerved.

Though the vapour obtained in this manner be chiefly ſulphurous acid gas; yet its effects are not leſs intereſting on that account.

EXP. 1. GOLD.

A bit of ſilk was dipped in a ſolution of gold in ether, and dried: it was then ſuſpended in the glaſs funnel, and expoſed for ſome time to the vapour obtained from a burning match: but no change could be perceived, except that the ſilk became a little brown.

Another bit of ſilk, prepared in the ſame manner, was immerſed in the vapour of ſulphur, formed in a phial placed in hot ſand, with the ſame reſult.

EXP. 2. GOLD.

A piece of ſilk was immerſed in a ſolution of nitro-muriate of gold in water, ſuſpended in the glaſs funnel, and expoſed, while wet, to vapour of ſulphur, formed by a burning match; no ſooner did the vapour touch the ſilk, than the reduction commenced; and in a few ſeconds the whole piece was covered with a ſplendid coat of reduced gold, permanent, and retentive of its luſtre; but had a few ſpecks of a dull violet hue.

The ſilk viewed by tranſmitted light appeared of a beautiful blue colour; and being removed from the vapour, and ſuſpended in the air, began in about ten minutes to exhale a vapour, which continued about two hours, and ſmelled acid, and pungent.

Another bit of ſilk, dipped in the ſame ſolution of gold, and dried, was wetted with alcohol, and expoſed to the ſame vapour: the ſilk acquired a browniſh hue; and a ſmall white metallic film appeared on its lower end, where the alcohol moſt abounded: the ſilk was then wetted with water, and replaced in the vapour; inſtantly a lively purple with a bright pellicle of reduced gold appeared.

EXP. 3. SILVER.

A piece of ſilk was immerſed in a ſolution of nitrate of ſilver in water, and ſuſpended in the air of a dark cloſet to dry; the ſilk retained its white colour, though it remained in the air twenty-four hours; it was then expoſed fourteen hours to the vapour obtained from a burning match; but ſuffered no change, except that it acquired a brown tinge: it was now wetted with alcohol, and replaced in the vapour for ſome time; no ſigns of reduction appearing, it was wetted again with the alcohol, and expoſed to the vapour; but ſtill no ſigns of reduction could be perceived: I then wetted the ſilk with diſtilled water, replaced it in the ſulphureous vapour; and in about a minute reduced ſilver appeared.

EXP. 4. SILVER.

I dipped a bit of ſilk in a ſolution of nitrate of ſilver in diſtilled water, and expoſed it, while wet, to the vapour of ſulphur, as in the preceding experiment; in a few ſeconds the ſilver appeared in its metallic form, attended with a variety of lively colours: the moſt remarkable of theſe were a pleaſant blue, orange, purple, and yellow, which ſoon diſappeared: the reduced ſilver alſo diſappeared in a great meaſure, ſome faint traces only remaining. The ſilk was removed from the vapour into the air, but exhaled no vapour, as happened in experiment the ſecond.

A ſmall bit of ſulphur was ſuſpended in a phial containing a ſolution of nitrate of ſilver in water; and after ſome weeks the ſulphur was coated with reduced ſilver of no great luſtre.

EXP. 5. PLATINA.

A bit of ſilk was immerſed in a ſolution of nitro-muriate of the ore of platina in diſtilled water, and dried in the air; it was then ſuſpended in the glaſs funnel, and expoſed to the vapour of a burning match: but no ſigns of reduction could be obſerved: the ſilk retained the colour, the ſolution gave it.

Another bit of ſilk was dipped in the ſame ſolution of platina, and expoſed, while wet, to the ſulphureous vapour; in a few ſeconds the reduction was very evident. The ſilk was immerged in a glaſs of clear water, and transferred bright films of reduced platina to the ſurface of that fluid; moſt of them were of the ſame colour as the ſpangles in the ore of platina; and ſome were diſtinguiſhed by lively blue and purple colours.

Another bit of ſilk, dipped in the ſame ſolution of platina, was immerſed, while wet, in the vapour of ſulphur, formed in a phial placed in hot ſand; the reduction ſoon commenced, and was much more perfect, and permanent, than in pieces expoſed to the vapour obtained from ignited matches.

It is remarkable that ſulphur reduced this metal much better, than phoſphorus or hydrogen gas did: but the reduced platina diſappears after ſome time, and leaves nothing behind but a brown ſtain.

If the films be transferred from the ſilk to water, they may be preſerved in their metallic form.

EXP. 6. MERCURY.

A bit of ſilk was immerſed in a ſolution of nitrate of mercury in diſtilled water, and dried; parts of the ſilk immediately acquired a ſlate colour: the ſilk was then expoſed to the vapour of ſulphur, obtained from a burning match; but it ſuffered no change, except that the colour became a little more intenſe.

Another bit of ſilk was dipped in the ſame ſolution of mercury, and expoſed, while wet, to the ſame vapour: the reduction inſtantly commenced in a very evident manner, accompanied with ſeveral colours, as blue, purple, and yellow.

The ſilk was removed from the vapour, and ſoon loſt moſt of its luſtre, which was ſucceeded by a ſlate colour, through which ſome particles of reduced mercury were obſerved to ſhine.

EXP. 7. MERCURY.

A bit of ſilk was immerſed in a ſolution of oxygenated muriate of mercury in water, and dried in the air: it was then expoſed to the ſulphureous vapour obtained from a burning match; but the ſilk underwent no viſible change. This ſolution of mercury does not change the white colour of ſilk, as that of nitrate does.

Another bit of ſilk was dipped in the ſame ſolution of oxygenated muriate of mercury, and expoſed, while wet, to the vapour; in a few ſeconds reduced mercury appeared, unattended by any colour, except a ſlight tinge of citron yellow on part of the ſilk. After ſome time the whole of the reduced mercury vaniſhed.

EXP. 8. COPPER.

A piece of ſilk was immerſed in a ſolution of ſulphate of copper, and dried; it was then ſuſpended in the glaſs funnel, and expoſed to the vapour obtained from a burning match; but the ſilk ſuffered no change, retaining the colour, which the ſolution gave it.

Another bit of ſilk was dipped in the ſame ſolution of copper, and expoſed, while wet, to the vapour of an ignited match; in a ſhort time a white metallic film appeared, accompanied with a brown tinge: the ſilk becoming dry, was wetted with water, and expoſed to a briſk vapour from another match: the film became more evident, and parts of it verged on yellow, bordering on a copper colour. After ſome time this white metallic film diſappears, and nothing remains but a light brown ſtain.

EXP. 9. LEAD.

A bit of ſilk was immerſed in a ſolution of acetite of lead in diſtilled water, and dried in the air: it was then expoſed to the ſulphureous vapour of a burning match; but underwent no viſible change whatever.

Another bit of ſilk was dipped in the ſame ſolution of lead, and expoſed, while wet, to the vapour; reduced lead ſoon appeared all over the ſilk; but after ſome time this reduced lead diſappears, unleſs it be transferred to the ſurface of water.

EXP. 10. TIN.

A bit of ſilk was immerſed in a ſolution of muriate of tin in diſtilled water, and dried in the air: it was then expoſed to the vapour obtained from a burning match, which ſoon filled the glaſs; but produced no viſible change on the ſilk.

Another bit of ſilk was dipped in the ſame ſolution of tin, and expoſed, while wet, to the ſulphureous vapour; and in a few ſeconds reduced tin appeared all over the ſilk; but the tin ſoon diſappears, if not transferred to water.

EXP. 11. ARSENIC.

A bit of ſilk was immerſed in a ſolution of muriate of arſenic in diſtilled water, and dried in the air; it was then expoſed to the vapour of ſulphur, obtained from a burning match; but the ſilk ſuffered no apparent alteration.

Another bit of ſilk was dipped in the ſame ſolution of arſenic, and expoſed, while wet, to the vapour: in a few ſeconds the arſenic was reduced, but not in a very evident manner; the ſilk was immerged in water, and ſeveral bright films of reduced arſenic floated on the ſurface of that fluid.

EXP. 12. BISMUTH.

A bit of ſilk was immerſed in a ſolution of nitrate of biſmuth in diſtilled water, and dried in the air; it was then expoſed to the vapour of ſulphur obtained from a burning match; but no ſigns of reduction appeared.

Another bit of ſilk was dipped in the ſame ſolution of biſmuth, and expoſed, while wet, to the ſulphureous vapour; the biſmuth was ſoon reduced, accompanied with a brown ſtain: but the metallic luſtre ſoon diſappeared.

EXP. 13. ANTIMONY.

A piece of ſilk was immerſed in a ſolution of tartarite of antimony in water, and dried; it was then expoſed to the vapour of a burning match; but no change could be obſerved; nor did the ſilk immerged in water depoſit any films on its ſurface.

Another piece of ſilk was dipped in the ſame ſolution of antimony, and expoſed, while wet, to the vapour: the ſilk, in a few ſeconds, acquired a yellow colour, and a bright bluiſh film of reduced antimony appeared on the lower end of the ſilk, where the water was moſt abundant: the ſilk was then immerged in a glaſs of water, and transferred a large pellicle of reduced antimony to the ſurface of that fluid.

EXP. 14. IRON.

A bit of ſilk was immerſed in a largely diluted ſolution of ſulphate of iron in diſtilled water, and dried in the air; it was then expoſed to the vapour of ſulphur obtained from a burning match; after ſome time the colour of the ſilk became a little brown; but no reduced iron could be ſeen; nor did the ſilk immerged in a glaſs of clear water transfer any thing metallic to its ſurface.

Another bit of ſilk was dipped in the ſame ſolution of iron, and expoſed, while wet, to the ſulphureous vapour; in a ſhort time the ſilk was withdrawn, and a minute ſhining film, of a livid white colour, was viſible on its lower margin, where the water moſt abounded: the ſilk was then immerged in a glaſs of water, and transferred a large film of reduced iron to its ſurface.

This experiment ſucceeded alſo with the vapour of ſulphur formed in a phial placed on hot ſand. The films of reduced iron were ſeldom viſible on the ſilk; but were ſoon rendered viſible, by transferring them to water.

EXP. 15. ZINC.

A piece of ſilk was dipped in a diluted ſolution of ſulphate of zinc, and dried; it was then expoſed to the vapour obtained from a burning match; no change whatever could be perceived: the ſilk was immerged in a glaſs of water, but depoſited no film on its ſurface.

Another piece of ſilk was dipped in the ſame ſolution of zinc, and immerſed while wet in the vapour of ſulphur formed in a phial placed on hot ſand; in about half a minute the ſilk was withdrawn from the vapour, and ſome parts of it had a ſhining livid appearance, which I took for reduced zinc: in order to determine if the reduction were real, the ſilk was immerged in a glaſs of clear water, and transferred to its ſurface a bright film of reduced zinc.

If the ſilk be kept too long in the vapour, ſome ſulphur will be condenſed on its ſurface, and give it a yellow colour: if it be then dipped in a glaſs of water, it will depoſit both the ſulphur, and the metallic films on its ſurface; but the appearance of the ſulphur is ſo different from that of the reduced metal, that they are eaſily diſtinguiſhed.

Another bit of ſilk was immerſed in a largely diluted ſolution of muriate of zinc, and expoſed, while wet, to the vapour obtained from a burning match: the ſilk being withdrawn exhibited a few minute ſhining films on its lower end, and on immerſion in water, left bright films of reduced zinc floating on the ſurface of that fluid.

Very often theſe films cannot be ſeen, until they are transferred to water, which I found a very uſeful teſt in doubtful caſes: they are better ſeen in the gray light than in ſunſhine.

Theſe experiments on the reduction of metals by ſulphur were often repeated with nearly the ſame reſult: but ſome variety occurs depending on the quantity of water preſent, the ſtrength of the metallic ſolution, and ſulphureous vapour, and alſo on the time the ſilk is expoſed to the vapour.

When the experiments are made in a phial placed in hot ſand, part of the metallic ſolution frequently drops from the ſilk, and falling on the bottom, or ſides of the phial, is reduced, covering theſe parts with a metallic cruſt; on which the ſulphur ſoon reacts, and changes the greater part into a ſulphure. The phial commonly cracks.

The following concluſions are deducible from the experiments related in this chapter.

1. Water is eſſential to the reduction of metals by ſulphur; for this effect is always in proportion to the quantity of water preſent.

2. Alcohol does not promote theſe reductions without the aid of water.

3. Sulphur does not reduce the metals by

giving them phlogiſton; nor by uniting with and ſeparating their oxygen; for were either of theſe opinions juſt, the ſulphur, ſo minutely divided by heat, ſhould reduce metallic ſolutions in alcohol as effectually as it does metallic ſolutions in water.

When we compare theſe reductions by ſulphur, with thoſe effected by phoſphorus, and conſider that water is eſſential to both; we muſt conclude, that the reduction is effected in the ſame manner, viz. by the decompoſition of water; which may be thus explained.

The ſulphur attracts the oxygen of the water, while the hydrogen of the latter unites, in its naſcent ſtate, to the oxygen of the metal, and reſtores it to the metallic form.

Hence it follows, that the ſulphur is oxygenated by the oxygen of the water, while the metal is reſtored to its combuſtible ſtate.

It alſo follows, that a quantity of water equal to that conſumed is formed by the hydrogen of the water, and the oxygen of the metal.

This explanation is ſupported by a fine experiment of Dr. Prieſtley, who obtained inflammable air by paſſing the vapour of water through ſulphur heated in an earthen tube*; and farther confirmed by the experience of ſome judicious makers of oil of vitriol, who always ſprinkle the ſulphur with a certain proportion of water, before they inflame it.

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* Prieſtley, Vol. VI. p. 150.

The decompoſition of water in theſe reductions muſt be granted, or it muſt be ſuppoſed, that a ſingle takes place in preference to a double affinity; which cannot be admitted.

Theſe experiments point out ſeveral errors in M. Lavoiſier's Table of the Affinities of the Oxygenous Principle; for he has placed ſulphur at a much greater diſtance from that principle than any of the metals treated of in this chapter, except gold; and even in this inſtance his table is erroneous, unleſs it be proved, that ſulphur reduces metals by directly uniting with, and ſeparating their oxygen; a ſuppoſition which implies, that the reduction is effected by a ſingle affinity; and therefore inadmiſſible.

I ſhall cloſe this chapter with a ſhort extract from the chemical eſſays of Biſhop Watſon; as it ſeems to have ſome relation to the experiments related here.

His lordſhip ſays, that his experiments on "the Derbyſhire lead ore inſtruct us to believe, that the lead in this kind of ore is in its metallic ſtate; as the ore was changed into lead without the addition of any ſubſtance containing the inflammable principle [*]."

But the reduction of lead by ſulphur and water, related in this chapter, points out an evident ſource of the inflammable principle; for the ore itſelf muſt contain ſome water, a conſtituent part of which is hydrogen, or the baſe of inflammable air: beſide his lordſhip thinks, no appearance of lead would have taken place, had there been no communication with the external air: but as air always holds water in ſolution, an ample ſource of the inflammable principle is evident.

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[*] Chem. Eſſays, Vol. III. p. 219.

CHAPTER III.

Reduction of Metals by Alkaline Sulphure.

THE Sulphure, I made uſe of, was prepared by fuſing equal parts of carbonate of potaſh, and flowers of ſulphur, till the efferveſcence ceaſed.

M. Gengembre has made a very important obſervation on alkaline ſulphure, prepared in this way, which is, that this ſubſtance has no ſmell, and that it exhales no gas, while it continues dry; but that, when it is diſſolved in water, or attracts humidity from the air, it diffuſes an offenſive ſmell.

From this circumſtance M. Gengembre inferred, that the diſengagement of this gas depended on the decompoſition of water; for he diſcovered both by analyſis, and ſyntheſis, that this air conſiſts of hydrogen, one of the principles of water, combined with ſulphur, and caloric.

There can then be no doubt, but alkaline ſulphure has the power of decompoſing water; and may therefore be happily employed to illuſtrate the mode of action of ſulphur, and other combuſtible ſubſtances, treated of in this eſſay.

When diluted acids are poured on ſolid alkaline ſulphure, the decompoſition of the water is promoted, and accelerated, ſulphurated hydrogen gas being formed in great abundance.

I made two ſolutions of this alkaline ſulphure, one in water, and the other in alcohol.

EXP. I. GOLD.

A bit of ſilk was immerſed in the ſolution of ſulphure in alcohol, and then a ſolution of gold in ether was applied: a brown matter was formed in the ſilk; but no reduced gold could be perceived.

Another bit of ſilk was dipped in the ſame ſolution of ſulphure in alcohol, and a ſolution of nitro-muriate of gold in water was applied; a white metallic film was ſlowly formed; but no other ſigns of reduction were viſible.

This experiment was repeated on another bit of ſilk, with this difference, that the ſolutions of the gold, and ſulphure, were both in water; and the white metallic film was inſtantly formed, accompanied by a conſiderable precipitate of a brown matter.

It is obvious then, that water accelerates, and is neceſſary to the appearance of this film: for when both ſolutions were in water, it appeared much ſooner.

EXP. 2. GOLD.

A piece of ſilk was immerſed in an aqueous ſolution of gold, in which the acid predominated, then a few drops of the aqueous ſolution of ſulphure were applied: a white pellicle, which looked like ſilver, was immediately formed, and the ſilk got a deep brown colour.

To another piece of ſilk, dipped in the ſame ſolution of gold, the ſolution of ſulphure in alcohol was applied, a white metallic film appeared; but not ſo evident, or ſo ſoon, as in the preceding experiment, wherein the ſolution of ſulphure in water was uſed: beſide the film produced by the aqueous ſolution of ſulphure was more permanent, and the ſtain, which the ſilk acquired, was more intenſe, than thoſe produced by the ſolution of ſulphure in alcohol.

EXP. 3. SILVER.

I immerſed a piece of ſilk in a ſolution of the ſulphure in alcohol, and after moſt of the ſpirit evaporated, a ſolution of nitrate of ſilver in alcohol was applied: nothing appeared on the ſilk, but a brown ſtain. The nitrate of ſilver, uſed in this experiment, was fuſed, to expel as much water as poſſible.

Another piece of ſilk was dipped in the ſame ſolution of ſulphure; when moſt of the alcohol evaporated, a ſolution of cryſtallized

lized nitrate of ſilver in water was applied to the ſilk; and inſtantly the metallic luſtre of the ſilver appeared, attended with a brown ſtain.

EXP. 4. SILVER.

A piece of ſilk was dipped in the ſolution of alkaline ſulphure in water, and an aqueous ſolution of cryſtallized nitrate of ſilver was applied; the ſilver was immediately reduced in greater quantity than in the preceding experiment, in which the alkaline ſulphure employed was diſſolved in alcohol. The ſtain produced in the ſilk was alſo more intenſe.

EXP. 5. SILVER.

A bit of ſilk was immerſed in a ſolution of the ſulphure in water, and then a ſolution of nitrate of ſilver in alcohol was applied: but nothing appeared on the ſilk, except a brown ſtain. The nitrate of ſilver, uſed in this experiment, was fuſed, which deprived it of a great part of its acid. That this was the circumſtance, which prevented the reduction of the ſilver, appears from the following experiment.

A bit of ſilk was immerſed in the ſame ſolution of ſilver in alcohol, then ſome diluted nitric acid was applied, laſtly the aqueous ſolution of ſulphure was dropped on the ſilk: and inſtantly the ſilver was reſtored to its metallic ſplendour. It is evident then, that acids contribute to the reduction of ſilver by alkaline ſulphure, which they effect by promoting the decompoſition of water.

In ſome time the reduced ſilver diſappears for the moſt part: and indeed the white metallic films, which were produced in the experiments on gold, totally diſappeared.

EXP. 6. PLATINA.

A bit of ſilk was immerſed in a ſolution of nitro-muriate of the ore of platina in diſtilled water, and dried; then the ſolution of ſulphure in alcohol was dropped on the ſilk: nothing appeared but a brown ſtain.

Another bit of ſilk was dipped in the aqueous ſolution of ſulphure, and a little of the ſolution of platina applied; in a ſhort time, a film of reduced platina appeared.

To another bit of ſilk, which was dipped in the ſolution of platina, a few drops of diſtilled vinegar were applied, and then the ſolution of ſulphure in water was added; a brown ſtain was immediaaely produced, and more platina reduced than in the preceding experiment.

EXP. 7. MERCURY.

To a bit of ſilk, which was immerſed in a ſolution of oxygenated muriate of mercury in water, and dried in the air; ſome of the ſolution of ſulphure in alcohol was applied;

but no change, except a light yellowiſh brown, was produced.

After the ſilk was ſome time expoſed to the air, ſome very faint ſhades of black were viſible on parts of it.

To a piece of ſilk, which was immerſed in the ſolution of ſulphure in water, ſome of the ſame ſolution of mercury was applied; immediately the metal was reſtored to its metallic luſtre, in a very ſtriking manner; and it was remarkable, that the precipitate on the ſilk was very ſmall.

This experiment was repeated with this difference, that the ſilk was firſt wetted with diſtilled vinegar: and more of the mercury was reduced, than in the preceding experiment, attended with an olive precipitate, which gradually turned blackiſh: the quantity of precipitated matter in this was much greater than in the former experiment; but the reduced metal was not ſo bright.

EXP. 8. MERCURY.

A bit of ſilk, which was dipped in a ſolution of nitrate of mercury, and dried in the air, had no change produced on it by a ſolution of ſulphure in alcohol, except a ſtain compounded of the ſlate colour, which the nitrate imparts, and the yellow of the ſulphure..

To another bit of ſilk, which was immerſed in the aqueous ſolution of ſulphure, ſome of the ſame ſolution of mercury was applied: the metal was immediately reduced; and a very black ſtain attended the reduction.

EXP. 9. COPPER.

A piece of ſilk was dipped in a ſolution of ſulphate of copper, and dried in the air; a ſolution of the ſulphure in alcohol was applied to it; but no change, except a brown ſtain, was produced.

To another bit of ſilk, immerſed in the aqueous ſolution of ſulphure, ſome of the ſame ſolution of copper was applied: a white metallic film was ſlowly formed, attended with a brown colour.

On another bit of ſilk, which was dipped in the ſame ſolution of copper, and placed on a ſaucer, ſome diſtilled vinegar was dropped, and then a few drops of the aqueous ſolution of ſulphure were added: immediately a white metallic film appeared in greater quantity than in the preceding experiment.

EXP. 10. LEAD.

A piece of ſilk was immerſed in a ſolution of acetite of lead in diſtilled water, and dried in the air; then the ſolution of ſulphure in alcohol was applied: but nothing appeared on the ſilk, except a brown ſtain.

A bit of the ſame ſilk was dipped in the ſame ſolution of lead, then the ſolution of ſulphure in water was applied: the lead was ſoon reduced to its metallic ſtate: a brown ſtain, and precipitate of the ſame colour, attending the reduction.

The ſame experiment was repeated with this difference, that the ſilk was firſt wetted with diſtilled vinegar, and inſtantly the lead was reduced of greater luſtre, and in greater quantity, than in the preceding experiment.

This experiment was tried on a bit of white calico, dipped in diſtilled vinegar, and placed on the palm of my hand; and inſtantly the metallic luſtre of the lead, which was reduced in great quantity, appeared in a very remarkable manner, attended with a brown ſtain.

EXP. 11. TIN.

To a bit of ſilk dipped in a ſolution of muriate of tin in diſtilled water, and dried in the air, the ſolution of ſulphure in alcohol was applied: nothing appeared but a brown ſtain.

Another bit of ſilk was immerſed in the ſolution of ſulphure in water, then the ſame ſolution of muriate of tin was applied; in a ſhort time ſome reduced tin appeared on the ſilk. Vinegar promoted the reduction of this metal alſo, in a remarkable manner.

EXP. 12. ARSENIC.

A bit of ſilk was immerſed in a ſolution of muriate of arſenic in diſtilled water, and dried in the air: the ſolution of ſulphure in alcohol was then applied: the ſilk firſt looked yellow, in a ſhort time the yellow colour almoſt entirely diſappeared, leaving behind a whitiſh precipitate; but no other change was produced.

Another bit of ſilk was dipped in the ſolution of ſulphure in water; then ſome of the ſame ſolution of arſenic was applied; a yellow precipitate was formed; and ſhortly after, this precipitate was ſurrounded by a violet margin; but no other change could be obſerved.

I immerſed another bit of the ſame ſilk in the ſame ſolution of arſenic, ſome diſtilled vinegar was then dropped on it; and laſtly the aqueous ſolution of ſulphure was applied: after ſome time, a few minute films of reduced arſenic bright as ſilver were viſible.

Some attention is neceſſary to diſcover the reduced arſenic, as the particles reduced are few, and minute; and ſometimes none can be ſeen.

EXP. 13. BISMUTH.

To a bit of ſilk, which was dipped in a ſolution of nitrate of Biſmuth in diſtilled water, and dried in the air, the ſolution of ſulphure in alcohol was applied: the ſilk appeared firſt yellow, then brown; but no farther change could be obſerved.

Another bit of ſilk was immerſed in the ſolution of ſulphure in water; ſome of the ſame ſolution of biſmuth was then applied to it; the metal was immediately reduced; and a brown precipitate was formed. Vinegar ſeems neither to promote, nor retard the reduction.

Two bits of white calico were dipped in the ſame ſolution of biſmuth; to one of theſe placed on a ſaucer ſome diſtilled vinegar was added; then a ſingle drop of the ſolution of ſulphure in water was applied; and the whole of the calico, except that part on which the drop fell, was covered with reduced biſmuth, which looked exceedingly bright: the ſame appearance was obſerved on the other bit, to which no vinegar was added.

EXP. 14. ANTIMONY.

To a bit of ſilk, which was dipped in a ſolution of tartarite of antimony in diſtilled water, and dried in the air, the ſolution of ſulphure in alcohol was applied; the ſilk got a yellow colour, whoſe margins, ſome time after, acquired an orange hue; but no other change was perceived.

Another bit of the ſame ſilk was immerſed in the aqueous ſolution of ſulphure, the ſame ſolution of antimony was then applied: part of the metal was reduced, though in ſmall quantity, attended with an orange precipitate.

The acids of vinegar, and tartar, ſeemed to impede the reduction; the muriatic acid alſo ſeemed to have the ſame effect, though not in ſo great a degree as the two former.

Exp. 15. Cobalt.

To a bit of ſilk, which was dipped in a ſolution of nitrate of cobalt, and dried in the air, the ſolution of ſulphure in alcohol was applied; the ſilk ſoon became brown; but no farther change could be perceived.

To another bit of ſilk, which was immerſed in the ſolution of ſulphure in water, a few drops of the ſame ſolution of cobalt were applied: the ſilk immediately acquired a dark colour, and, in a little time, ſome of the metal was reduced, attended with a dull blue precipitate, which changed to a blackiſh brown.

Muriate of cobalt was reduced in the ſame manner: vinegar promoted the reduction of both theſe preparations of cobalt.

Exp. 16. Iron.

To a piece of ſilk, which was immerſed in a ſolution of ſulphate of iron largely diluted, and dried in the air, the ſolution of ſulphure in alcohol was applied: the ſilk ſoon became black; but no other change could be perceived.

Another bit of ſilk was dipped in the ſolution of ſulphure in water, ſome of the ſame ſolution of iron was then applied: the ſilk inſtantly aſſumed a black colour; but no reduced iron appearing, it was immerged in a glaſs of water, and transferred a bright film of reduced iron to the ſurface of that fluid.

Sometimes part of the film has not the metallic luſtre, which is very evident in other parts of it; ſo that the parts completely reduced can be eaſily diſtinguiſhed from the dull and imperfectly reduced black oxid of iron, intermixed with theſe bright films.

The ſame experiments were repeated on bits of calico with the ſame reſult: the calico from its ſpongy texture is better ſuited to produce ſtrong films than ſilk is.

Vinegar did not promote the reduction of iron in theſe experiments.

EXP. 17. ZINC.

To a bit of ſilk, which was immerſed in a largely diluted ſolution of muriate of zinc, and dried in the air, ſome of the ſolution of ſulphure in alcohol was applied; nothing appeared on the ſilk, but the yellow colour, which the ſolution of ſulphure imparts.

Another bit of ſilk was dipped in the ſolution of ſulphure in water, and ſome of the ſame ſolution of zinc was applied: the yellow colour, which the ſolution of ſulphure gave the ſilk, ſoon became white; but no reduced zinc could be ſeen. The ſilk was then immerged in a glaſs of clear water, and transferred a bright film of reduced zinc to its ſurface.

In another experiment, made with white calico, the pellicle transferred to the ſurface of water was brighter; and more zinc was reduced, than in the preceding experiment.

Sulphate of zinc alſo was reduced both on ſilk, and calico, with this difference that black, and olive, precipitates, attended the reduction.

EXP. 18. MANGANESE.

I dipped a bit of ſilk in a diluted ſolution of nitrate of manganeſe, and dried it in the air; the ſolution of ſulphure in alcohol was then applied: the ſilk acquired a yellow colour, which ſoon diſappeared; but no other change could be obſerved.

To another bit of ſilk, which was immerſed in the ſolution of ſulphure in water, a drop of the ſame ſolution of manganeſe was applied: inſtantly a pearl-white precipitate was formed, the margin of which ſoon acquired a bright film of reduced manganeſe. Under this film a violet tinge was evident.

The nitrate of manganeſe uſed in this experiment was very acid.

A ſolution of alkaline ſulphure in water after a certain length of time loſes the power of reducing the metals, in which reſpect it reſembles an old ſolution of ſulphate of iron.

Having procured a more neutral ſolution of nitrate of manganeſe, I immerſed a bit of ſilk in the ſolution of ſulphure in alcohol, when moſt of the ſpirit evaporated; a ſingle drop of this ſolution of manganeſe was applied; inſtantly a bright film of reduced manganeſe appeared, attended with a violet tinge, and a brown precipitate. After ſome time the violet tinge diſappears.

On another bit of ſilk immerſed in the ſame ſolution of ſulphure in alcohol, a drop of a ſolution of ſulphate of manganeſe in diſtilled water was applied: inſtantly films of reduced manganeſe bright as ſilver appeared, accompanied with a faint violet tinge, and a pearl-white precipitate. Theſe films ſoon diſappear.

A ſolution of alkaline ſulphure in alcohol does not by age loſe its power of reducing the metals, as that in water does; I kept the former ſolution more than two years, and found it, at the end of that time, as capable of reducing the metals, as when it was made.

It is manifeſt from the experiments related in this chapter,

1. That water is eſſential to the reduction of metals by alkaline ſulphure.

2. That alcohol does not promote theſe reductions, without the aid of water.

3. That alkaline ſulphure does not reduce the metals by giving them phlogiſton; nor by uniting with, and ſeparating, their oxygen; for were either of theſe opinions true, a ſolution of alkaline ſulphure in alcohol ſhould reduce them as effectually, as a ſolution of the ſame in water does.

4. That acids contribute to theſe reductions by promoting the decompoſition of water.

Now ſince M. Gengembre has demonſtrated, that water is decompoſed by alkaline ſulphure; who can doubt, that it is decompoſed in theſe reductions?

The manner, in which metals are reduced by this ſubſtance, ſeems to be the following.

An hydrure of ſulphur, that is, a combination of hydrogen, and ſulphur, is formed: this hydrure of ſulphur attracts the oxygen of the water, while the hydrogen of the latter unites, in its naſcent ſtate, with the oxygen of the metal, and reduces it.

The experiments in this chapter leave us no room to doubt of the decompoſition of water in metallic reductions by alkaline ſulphure, and ſerve to illuſtrate, and confirm, the manner, in which ſulphur, phoſphorus, and other combuſtible bodies, effect the reduction of metals.

CHAPTER V.

REDUCTION OF METALS BY *SULPHURATED HYDROGEN GAS.*

HAVING treated of the effects of hydrogen gas, and ſulphur, ſeparately, I ſhall next treat of their effects, when combined in the form of ſulphurated hydrogen gas.

I obtained this elaſtic fluid by pouring water, acidulated with ſulphuric acid, on alkaline ſulphure, prepared in the manner mentioned in the preceding chapter; but had it been prepared with a cauſtic alkali, it is probable, the gas would be more powerful. The ſulphure of the ſhops is generally unfit for theſe experiments.

It is neceſſary in experiments with ſulphurated hydrogen gas, hydrogen gas, &c. to have ſome mode of conveying them into a chimney; as they are offenſive, and unwholeſome.

EXP. I. GOLD.

A piece of ſilk, which was immerſed in a ſolution of nitro-muriate of gold in water, and dried in the air, was expoſed to ſulphurated hydrogen gas: the ſilk got a ſlight tinge of brown; but no other change occurred: it was then wetted with alcohol, and after ſome time, the brown became more intenſe; and white films appeared on ſome parts of the ſilk, owing to moiſture collected from the gas, which is always replete with water.

Another bit of ſilk was dipped in the ſame ſolution of gold, and expoſed, while wet, to the gas: the yellow colour, which the ſolution of gold gave the ſilk, was immediately changed to a brown; and a white metallic pellicle appeared, and covered the whole ſurface of the ſilk oppoſed to the gas; but no purple, or other colours, that uſually attend the reduction of this metal by other agents, could be perceived. This pellicle did not entirely diſappear, as the ſilk became dry; though it loſt moſt of its luſtre, and looked more like ſilver, or ſome other white metal imperfectly reduced, than gold.

This elaſtic fluid, and alkaline ſulphure, have an effect on the reduction of gold, very different from that of the vapour of ſulphur, obtained from a burning match, which further appears from the following experiment, made with ſulphurated hydrogen gas, that happened to be mixed with ſome ſulphurous acid gas.

EXP. 2. GOLD.

A piece of ſilk, which was dipped in a ſolution of gold in ether, and dried in the air, was expoſed to a current of ſulphurated hydrogen gas, containing ſome ſulphurous acid gas; but no ſigns of reduction could be perceived: the ſilk was then wetted with alcohol; ſtill no viſible change was produced, except a brown ſtain, where the alcohol moſt abounded: this ſtain, after ſome minutes expoſure to atmoſpheric air, was covered with a white metallic film, which ſoon diſappeared: after ſome minutes, the ſilk was wetted with water, and expoſed again to the gas; a white metallic film immediately appeared, and the brown ſtain began to change ſlowly to a purple; the ſilk was ſoon covered with various colours, as blue, red, and orange; and ſome ſpots of reduced gold of its own proper colour appeared: after ſome time the white film, and all the colours, except the purple, diſappeared: ſome ſpecks of the perfectly reduced gold were permanent.

Another bit of ſilk, which was immerſed in an aqueous ſolution of gold, and expoſed to the ſame mixed gas, exhibited nearly the ſame appearances.

Exp. 3. Gold.

Having found that ſulphurated hydrogen gas had a powerful effect in reducing other metals, I was deſirous of trying its effects on a larger ſcale, thinking it might be attended with more ſucceſs: I therefore immerſed a quarter of a yard of ſilk in an aqueous ſolution

tion of gold, and expoſed it, while wet, to this gas in cloſe veſſels: the ſilk was ſoon covered with a white metallic pellicle, which diſappeared in a ſhort time: the experiment was continued about twelve hours, and, on withdrawing the ſilk from the gas, I could not perceive the ſmalleſt veſtige of reduced metal, or purple, or other colours, that conſtantly attend the reduction of gold.

The ſilk had a dull brown hue verging on a ſlate colour.

EXP. 4. SILVER.

A piece of ſilk, which was immerſed in a ſolution of nitrate of ſilver in water, and dried in the air, was expoſed to a current of ſulphurated hydrogen gas; but no change could be perceived for ſome time; at length, when the ſilk collected moiſture from the gas, ſome particles of reduced ſilver were viſible, accompanied by a brown ſtain.

Another piece of ſilk was dipped in the ſame ſolution of nitrate of ſilver, and expoſed, while wet, to the gas: the ſilver was inſtantly reduced all over the ſide of the ſilk oppoſed to the current: a great variety of beautiful colours, as red, orange, yellow, green, and blue, attended the reduction: moſt of theſe diſappeared; but part of the ſilver remained permanently reduced.

I found, that, if the ſilk be immerſed in a ſolution of ſilver in alcohol, and dried, and then moiſtened with water, and expoſed, while wet, to the gas, none of theſe colours appear.

This experiment was repeated on a quarter of a yard of ſilk in cloſe veſſels, and immediately both ſides of the ſilk were covered with reduced ſilver, attended with the ſame beautiful colours: the ſilk was left expoſed to the gas ſeven or eight hours; and being then examined, no reduced ſilver could be ſeen: nothing remained, but a ſtrange medley of colours, chiefly blue, green, purple, and orange, unequally mixed, ſome prevailing more than others in certain parts of the ſilk: however the die is by no means diſagreeable.

EXP. 5. SILVER.

A piece of ſilk, which was immerſed in a ſolution of fuſed nitrate of ſilver in alcohol, and dried in the air, was expoſed to a current of the gas; but no change could be perceived for ſome time: it was then wetted with alcohol, ſtill no alteration could be obſerved, till the ſilk attracted moiſture from the gas, when ſmall particles of reduced ſilver began to appear, attended with a brown ſtain.

If the ſilk immerſed in the ſolution of ſilver in alcohol, and expoſed while wet to the gas, be kept conſtantly wet with alcohol, theſe appearances take place ſooner.

A piece of ſilk, which was dipped in a ſolution of muriate of ſilver in ammonia, and expoſed, while wet, to the gas, had in a ſhort time its ſurface covered with reduced ſilver: but another piece of ſilk dipped in the ſame ſolution of ſilver, and dried, underwent no ſuch change.

EXP. 6. PLATINA.

A bit of ſilk, which was dipped in a ſolution of nitro-muriate of the ore of platina in diſtilled water, and dried in the air, was expoſed to a current of ſulphurated hydrogen gas; but underwent no perceptible change.

Another bit of ſilk was immerſed in the ſame ſolution of platina, and expoſed, while wet, to the gas; the whole ſurface of the ſilk, oppoſed to the current, was inſtantly covered with reduced platina, which ſoon loſt its luſtre; nothing remaining but a brown colour, with ſome faint veſtiges of the reduced metal.

This experiment was repeated on a bit of linen with the ſame reſult.

EXP. 7. MERCURY.

A bit of ſilk, which was dipped in a ſolution of oxygenated muriate of mercury in diſtilled water, and dried in the air, was expoſed to a current of the gas; the only viſible change produced was a ſlight ſhade of yellow on part of the ſilk.

Another bit of ſilk was immerſed in the ſame ſolution of mercury, and expoſed, while wet, to the gas: the mercury was immediately reduced; but ſoon loſt its luſtre: the gas reacting changed moſt of it to a ſubſtance of a dull white colour.

The ſame experiments were made with nitrate of mercury, with the ſame reſult.

EXP. 8. COPPER.

A bit of ſilk was immerſed in a ſolution of ſulphate of copper in diſtilled water, and ſuſpended in the air to dry; it was then expoſed to a current of the gas: the ſilk aſſumed a brown colour; but no other change appeared.

Another bit of ſilk was dipped in the ſame ſolution of copper, and expoſed, while wet, to the gas: a white metallic film, attended with a brown ſtain, immediately appeared: ſome parts had a yellow film approaching to the colour of copper: theſe films all diſappeared, leaving behind a brown ſtain: the parts, which were covered with the yellow film, reſembling copper, exhibited, after ſome time, a dull bluiſh diſagreeable matter.

EXP. 9. LEAD.

Having dipped a piece of ſilk in a ſolution of acetite of lead in diſtilled water, and dried it in the air, I expoſed it to a ſtream of the gas: the ſilk became a little brown; but no other change could be obſerved.

Another bit of ſilk was immerſed in the ſame ſolution of lead, and expoſed while wet to the gas; no ſooner did it touch the ſilk, than a brown tinge diffuſed itſelf, like a paſſing ſhadow, over the whole ſurface of the ſilk, accompanied with a bright coat of reduced lead, which reſembled ſilver.

The brown tinge, which the ſilk acquires, reſembles what happens when white paper is ſlightly ſinged by holding it near a burning body.

This experiment was repeated on a quarter of a yard of ſilk in cloſe veſſels; and the ſilk was immediately covered with a coat of reduced lead, which had the brilliance of ſilver, and was attended with a brown tinge: the experiment was continued ſeveral hours, after which the ſilk was examined, and found to have loſt all the argentine luſtre, which was ſucceeded by a ſparkling gray die: a ſulphure of lead, or galena, being formed in the fibres of the ſilk. The ſame experiment was repeated on two other pieces of ſilk with the ſame reſult.

This elaſtic fluid is ſo powerful a reducer of the metals, that if chambers, painted with white lead, have any conſiderable degree of moiſture, and are expoſed to is influence, the lead on the ſurface of the walls is reduced, and that chiefly where the humidity is moſt abundant: this effect, I obſerved, was produced, even at the diſtance of three chambers from the place, where the gas was formed: and the lead was reduced moſt evidently

dently behind the window-ſhutters where the moiſture of the wall was moſt conſiderable.

It is a common experiment with chymiſts, in order to ſhow the effects of this gas, to draw characters with a ſolution of ſugar of lead on paper, which they place over a glaſs of water, containing ſome alkaline ſulphure: in ſome time the characters drawn on the paper acquire a brown, or black colour, and become viſible; which amuſes the ſpectators.

But it is ſurpriſing, that the metal has never been reduced in this experiment even by chance; and not leſs ſo, why *lead* ſhould be ſingled out for this trial of ſkill, in preference to other metals, which are equally affected by this gas.

EXP. 10. TIN.

A piece of ſilk was dipped in a ſolution of muriate of tin in diſtilled water, and dried in the air; the ſilk, on expoſure to a current of the gas, ſcarce underwent any change, except a few brown ſpecks diſperſed over its ſurface.

Another bit of ſilk was immerſed in the ſame ſolution of tin, and expoſed, while wet, to the gas, which no ſooner touched the ſilk, than the ſurface oppoſed to the current was covered with reduced tin of great brightneſs: in ſome time various colours, as blue, orange, and a faint purple, appeared, and became more evident, as the reduction proceeded.

The gas does not react on this metal ſo much as on mercury, and ſome other metals: part of the reduced tin remained permanent; but moſt of it diſappeared, and left behind a diſagreeable brown ſtain.

EXP. 11. ARSENIC.

A bit of ſilk was immerſed in a ſolution of muriate of arſenic in diſtilled water, and dried in the air; it was then expoſed to a ſtream of ſulphurated hydrogen gas; but no change could be obſerved, except a faint tinge of citron yellow, which appeared on ſome parts of the ſilk.

Another bit of ſilk was dipped in the ſame ſolution of arſenic, and expoſed, while wet, to the gas: the arſenic was inſtantly reduced all over the ſurface, oppoſed to the gas, attended with a citron yellow colour.

The gas ſoon reacted on the reduced arſenic; and nothing remained but the yellow ſtain.

EXP. 12. BISMUTH.

I diſſolved ſome biſmuth in nitric acid, and evaporated the ſolution to dryneſs; the ſalt was then diſſolved in diſtilled water, and the ſolution depoſited a copious white precipitate, but retained a quantity of the metal ſufficient for theſe experiments.

In this ſolution of biſmuth a piece of ſilk was immerſed, and dried in the air; it was then expoſed to a ſtream of the gas: and the only viſible effect produced was a very faint tinge of brown.

Another bit of ſilk was dipped in the ſame ſolution of biſmuth, and expoſed wet to the gas: the ſilk was inſtantly covered with a bright pellicle of reduced biſmuth, which ſoon loſt moſt of its metallic luſtre, being changed by the reaction of the gas to a ſulphure.

Mr. Kirwan in his experiments on hepatic air, found, that nitrous ſolution of biſmuth, by mixture with a ſolution of hepatic air in water, changes to a reddiſh brown, and even aſſumes a metallic appearance.

He alſo found that nitrates of ſilver, lead, and acetite of lead, were precipitated black.

EXP. 13. ANTIMONY.

A piece of ſilk, which was immerſed in a ſolution of tartarite of antimony in diſtilled water, and dried in the air, was expoſed to a ſtream of the gas; but ſuffered no viſible change, except that a few ſpecks of yellow, and orange appeared.

A bit of ſilk was dipped in the ſame ſolution of antimony, and expoſed, while wet, to the gas; the antimony was immediately reduced to its metallic form, attended with a deep orange colour: in ſome time, moſt of the metallic luſtre diſappeared, a few ſpecks only remaining permanent.

EXP. 14. IRON.

A piece of ſilk was immerſed in a diluted ſolution of ſulphate of iron in diſtilled water, and dried; it was then expoſed to a current of the gas; but underwent no viſible change.

Another bit of ſilk was dipped in the ſame ſolution of iron, and expoſed, while wet, to the gas: the ſilk ſoon began to acquire a dark colour, which gradually increaſed, and, at length, became black, attended with an obſcure metallic film. The ſilk was immerſed in water, and depoſited a bright metallic film on the ſurface of that fluid.

EXP. 15. ZINC.

A bit of ſilk, which was immerſed in a diluted ſolution of ſulphate of zinc in diſtilled water, and dried in the air, was expoſed to a current of the gas; but underwent no viſible change.

Another bit of ſilk was dipped in the ſame ſolution of zinc, and expoſed, while wet, to the gas; but no change in the colour of the ſilk, or ſign of reduction could be perceived: the ſilk was then immerged in a glaſs of clear water, and tranſferred to its ſurface a bright metallic film of the colour of zinc.

When a languid ſtream of gas was employed in theſe experiments, the films transferred to water were ſcarce viſible.

Exp. 16. Zinc.

A piece of ſilk, which was immerſed in a largely diluted ſolution of muriate of zinc, and dried in the air, was expoſed to a briſk current of ſulphurated hydrogen gas; but underwent no viſible alteration.

Another bit of ſilk was dipped in the ſame ſolution of zinc, and expoſed, while wet, to the ſame briſk current of gas; inſtantly the ſurface of the ſilk, oppoſed to the gas, was covered with a bright coat of reduced zinc, attended with faint orange, and purple colours.

Though the reduced zinc was quite evident; yet I had the curioſity to examine its appearance on the ſurface of water; I therefore immerſed the ſilk in a glaſs of that fluid, and a bright metallic pellicle, which retained the texture of the ſilk, as wax retains the impreſſion of a ſeal, was transferred to its ſurface.

Another bit of ſilk, dipped in the ſame ſolution of zinc, and expoſed for a longer time to the gas, loſt its metallic luſtre, the zinc being changed to a ſulphure by the reaction of the gas.

Theſe experiments on ſulphate, and muriate of zinc, ſhow, that the acid, in which the metal is diſſolved, influences the reduction in a remarkable manner.

It is evident from the experiments related in this chapter,

1. That water is eſſential to the reduction of metals by ſulphurated hydrogen gas.

2. That alcohol does not promote theſe reductions, without the aid of water.

3. That ſulphurated hydrogen gas does not reduce the metals by giving them phlogiſton; nor by uniting with, and ſeparating, their oxygen: for were either of theſe opinions well founded; metallic ſolutions in alcohol ſhould be as effectually reduced by this gas, as metallic ſolutions in water are.

When we conſider, that alkaline ſulphure reduces the metals by decompoſing water; we have every reaſon to conclude, that ſulphurated hydrogen gas reduces them in the ſame manner; ſince the ſame circumſtances are neceſſary to both: the hydrure of ſulphur, which conſtitutes the baſe of this gas, attracts the oxygen of the water, while the hydrogen of the latter unites, in its naſcent ſtate, with the oxygen of the metal, and reduces it.

Hence it follows, that the hydrure of ſulphur is oxygenated by the oxygen of the water, while the metal is reſtored to its combuſtible ſtate.

CHAPTER VI.

REDUCTION OF METALS

BY

PHOSPHORATED HYDROGEN GAS.

THE effects of hydrogen gas and phoſphorus on the reduction of metals in the fibres of ſilk have been treated of ſeparately in the two firſt chapters; in this, I ſhall briefly treat of their effects, when combined in the form of phoſphorated hydrogen gas, which from its high degree of inflammability ſeemed well adapted to this purpoſe.

The ſpontaneous inflammation of this kind of air was known to M. Gengembre in 1783; and his experiments were publiſhed in Roſier's journal for October 1785.

Mr. Kirwan alſo, without any knowledge of M. Gengembre's experiments, diſcovered the ſame air, which he calls phoſphoric air, and publiſhed his experiments in the 76th volume of the Philoſophical Tranſactions for 1786.

This elaſtic fluid may be obtained by digeſting a ſolution of potaſh in water with about half its weight of phoſphorus in a heat ſufficient to melt the latter; and may be received in glaſs veſſels over mercury.

But finding it inconvenient to introduce pieces of ſilk prepared for theſe experiments over mercury in cloſe veſſels, I expoſed them to the gas, as it iſſued from the neck of the phial in which it was prepared.

Part of this elaſtic fluid is ſpontaneouſly inflammable; but the other has not that property, which M. Gengembre imputes to the preſence of carbonic acid; for the ſake of brevity, I ſhall deſign the latter by the term *gas*, or *phoſphorated hydrogen gas*; and the former by the epithets *ſpontaneouſly inflammable*, or *detonating* gas, which, I found, does not burn or ſcorch ſilk wetted with metallic ſolutions.

EXP. I. GOLD.

A piece of ſilk, which was immerſed in a ſolution of nitro-muriate of gold in diſtilled water, and ſuſpended in the air twelve hours to dry, was divided into three parts.

One of theſe was expoſed to a ſtream of phoſphorated hydrogen gas: the ſilk became brown, and its margins, which happened to touch the ſides of the phial, acquired a violet tinge: but no reduction took place.

Another of theſe parts was wetted with alcohol, and expoſed to the gas; but no ſigns of reduction could be perceived.

The remaining part was wetted with water, and was no ſooner expoſed to the gas, than the reduction commenced over the whole ſilk, which was ſoon covered with a bright coat of reduced gold.

EXP. 2. SILVER.

A piece of ſilk was dipped in a ſolution of fuſed nitrate of ſilver in alcohol, and dried in the air: it was then divided into three parts.

One of theſe, in order to diſſipate moiſture more effectually, was dried ſtill better by a gentle heat, and expoſed to the gas; the ſilk acquired a browniſh dark colour: but no other alteration could be perceived.

Another of theſe parts, which was alſo better dried by a gentle heat, was wetted with alcohol, and expoſed to the gas: the ſilk acquired a dark brown colour; but no other change could be obſerved.

The remaining part was wetted with water, and expoſed to the gas: the reduction commenced immediately, and in a ſhort time the ſilk was covered with reduced ſilver.

EXP. 3. PLATINA.

A piece of ſilk was immerſed in a ſolution of nitro-muriate of the ore of platina in diſtilled water, and dried in the air; it was then divided into three parts.

One of theſe parts was expoſed to the gas; but ſuffered no viſible change.

Another of them was wetted with alcohol, and expoſed to the gas; but underwent no perceptible change.

The remaining part was wetted with water,

ter, and expoſed to the gas: in about three or four minutes, a bright metallic film, of great luſtre, appeared on the ſide of the ſilk, oppoſed to the gas.

Another bit of ſilk, which was dipped in the ſame ſolution of platina, and expoſed, while wet, to the ſpontaneouſly inflammable gas, was immediately covered with reduced platina, which being transferred to the ſurface of water looked bright as ſilver, and retained the impreſſion of the ſilk.

EXP. 4. MERCURY.

A bit of ſilk, which was immerſed in a ſolution of nitrate of mercury in diſtilled water, and dried in the air, was expoſed to the gas; but underwent no viſible change.

Another bit of ſilk was dipped in the ſame ſolution of mercury, and dried: it was then wetted with alcohol, and expoſed to the gas; but no ſign of reduction appeared.

Another bit of ſilk was immerſed in the ſame ſolution of mercury, and expoſed to the gas; the metal was inſtantly reduced all over the ſilk; a great variety of beautiful colours attending.

A piece of ſilk was dipped in a ſolution of oxygenated muriate of mercury in diſtilled water, and dried in the air: it was then divided into two parts.

One of theſe was expoſed to the gas: no change appearing, it was wetted with alcohol,

hol, and expoſed again to the gas; but ſtill no alteration could be perceived.

The remaining part was wetted with water, and was no ſooner expoſed to the gas, than the mercury was reduced over the whole ſilk. No colours attended the reduction.

Mr. Kirwan introduced ſome precipitate per ſe to a ſmall portion of 'phoſphoric air: the precipitate ſoon grew black; and a white ſmoke appeared; in two days the precipitate remained ſolid; yet acquired a pale white colour, like that of ſteel: the air loſt its ſpontaneous inflammability *.

EXP. 5. COPPER.

A piece of ſilk, which was immerſed in a ſolution of ſulphate of copper in diſtilled water, and dried in the air, was divided into two parts.

One of theſe was expoſed to the gas; but no viſible change occurred.

The remaining part was wetted with water, and expoſed to the gas: in a few minutes a browniſh matter appeared in the ſilk; but nothing metallic could be ſeen: the ſilk was then dipped in a glaſs of clear water, and transferred a ſmall white metallic pellicle to its ſurface.

In another experiment, made with the ſpontaneouſly inflammable gas, a white me-

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* M. Kirwan, Phil. Tranſ. for 1786.

tallic pellicle was immediately formed, attended with a brown ſtain; this pellicle reſembled ſilver, or a white metal: but the gas ſoon reacted on it, and formed a diſagreeable brown matter in the fibres of the ſilk.

Exp. 6. Lead.

A bit of ſilk, which was dipped in a ſolution of acetite of lead in diſtilled water, and dried in the air, was expoſed to the gas; but ſuffered no viſible change.

Another bit of ſilk was immerſed in the ſame ſolution of lead, and expoſed, while wet, to the gas; but nothing metallic could be ſeen: the ſilk, however, on immerſion in water, transferred a few minute bright films to the ſurface of that fluid.

In another experiment, made with the detonating gas, the reduced films were more evident.

Exp. 7. Tin.

A bit of ſilk, which was dipped in a ſolution of muriate of tin in diſtilled water, and dried in the air, was expoſed to the action of the gas, without ſuffering any viſible alteration.

Another piece of ſilk was immerſed in the ſame ſolution of tin, and expoſed, while wet, to the gas; but no ſigns of reduction could be perceived: the ſilk was then immerſed in water, and transferred a delicate metallic film to its ſurface.

Exp. 8. Arsenic.

A bit of ſilk, which was immerſed in a ſolution of muriate of arſenic in diſtilled water, and dried in the air, was expoſed to the gas; but no change could be perceived.

Another bit of ſilk, immerſed in the ſame ſolution of arſenic, and expoſed, while wet, to the gas, acquired in a few minutes a brown ſtain; but nothing metallic could be ſeen on the ſilk; which, however, on being dipped in water, transferred a very minute film of reduced arſenic to its ſurface.

In another experiment, made with the detonating gas, the films of reduced arſenic were much more evident, of greater brilliance, and attended with a brown ſtain produced in the fibres of the ſilk.

Exp. 9. Bismuth.

A piece of ſilk, which was dipped in a ſolution of nitrate of biſmuth in diſtilled water, and dried in the air, was expoſed to the gas; but no alteration could be obſerved.

Another bit of ſilk was immerſed in the ſame ſolution of biſmuth, and expoſed, while wet, to the gas: the ſilk in two or three minutes got a brown ſtain, which gradually became more intenſe; and a very delicate metallic film appeared: the ſilk was then immerged in water, and transferred a bright film of reduced biſmuth to the ſurface of that fluid: the film retained the impreſſion of the ſilk.

Exp. 10. Antimony.

A bit of ſilk, immerſed in a ſolution of tartarite of antimony in diſtilled water, and dried in the air, was expoſed to the gas; but ſuffered no apparent change.

Another piece of ſilk was dipped in the ſame ſolution of antimony, and expoſed, while wet, to the gas; but no ſigns of reduction appeared: the ſilk was then immerged in water, to the ſurface of which, it transferred one ſmall ſpangle.

This experiment was repeated with the detonating gas, which with difficulty produced ſome ſparkling films: the ſilk was immerſed in water, and transferred the films to its ſurface.

A white matter was viſible in the fibres of the ſilk.

Exp. 11. Cobalt.

A piece of ſilk, immerſed in a ſolution of muriate of cobalt, and dried in the air, was expoſed to the gas; but ſuffered no viſible alteration.

Another bit of ſilk was dipped in the ſame ſolution of cobalt, and expoſed, while wet, to the gas: but no ſign of reduction appeared;

peared; nor did the ſilk transfer a film to water.

Another bit of ſilk was immerſed in a ſolution of nitrate of cobalt, and expoſed, while wet, to the detonating gas: no ſigns of reduction were viſible for ſome time; but at length a few ſmall ſpangles of the metal appeared on the ſilk, and were very brilliant, and when transferred to water, were ſtill more ſo: a white matter could be ſeen in the fibres of the ſilk.

EXP. 12. IRON.

A bit of ſilk was immerſed in a largely diluted ſolution of ſulphate of iron in diſtilled water, and dried: it was then expoſed to the action of the gas; but no alteration could be perceived.

Another bit of ſilk was dipped in the ſame ſolution of iron, and expoſed, while wet, to the gas: in a few minutes ſome parts of the ſilk acquired a light brown colour; but no reduced iron could be ſeen on the ſilk, which however transferred a very minute, and delicate film to water.

This experiment was repeated with a ſtrong detonating gas, and a very brilliant metallic film about four lines in diameter was reduced on the ſilk accompanied with a brown ſtain: but nothing like the black oxid of iron appeared.

Exp. 13. Zinc.

A bit of ſilk, which was immerſed in a largely diluted ſolution of muriate of zinc, was expoſed dry to the gas; but underwent no viſible alteration.

Another piece of ſilk was dipped in the ſame ſolution of zinc, and expoſed wet to the gas; no ſigns of reduction appearing, the ſilk was immerged in water, and left a very minute metallic film on its ſurface, which could with difficulty be ſeen.

The experiment was repeated with the detonating gas, and a very bright metallic film of zinc, four or five lines in diameter, was reduced on the ſilk.

This experiment ſucceeded alſo with a largely diluted ſolution of ſulphate of zinc.

The ſilk, viewed by tranſmitted light, exhibited a brown ſtain beneath theſe films of iron and zinc.

The experiments detailed in this chapter ſhow,

1. That water is eſſential to the reduction of metals by phoſphorated hydrogen gas.

2. That alcohol does not promote theſe reductions, without the aid of water.

3. That this elaſtic fluid does not reduce metals by giving them phlogiſton; nor by combining with, and ſeparating, their oxygen; for were either of theſe ſuppoſitions true, it ſhould reduce them as well with alcohol, as with water.

After explaining the manner, in which ſulphurated hydrogen gas reduces the metals; the mode of agency of phoſphorated hydrogen gas is ſufficiently obvious.

The gas attracts the oxygen of the water, while the hydrogen of the latter unites, in its naſcent ſtate, with the oxygen of the metal, and reduces it.

Hence it follows, that the hydrure of phoſphorus, which conſtitutes the baſe of this gas, is oxygenated by the oxygen of the water, while the metal is, at the ſame time, reſtored to its combuſtible ſtate.

By hydrure of phoſphorus is meant, a combination of hydrogen and phoſphorus, containing leſs caloric, than is neceſſary to the gazeous ſtate.

CHAPTER VII.

REDUCTION OF METALS
BY
CHARCOAL.

FINDING ſeveral combuſtible bodies, as hydrogen, phoſphorus, ſulphur, and combinations of theſe, capable of reducing the metals in the ordinary temperature of the atmoſphere; I was deſirous of knowing, if Charcoal alſo poſſeſſed that power.

Charcoal may be applied with this view in ſeveral forms. M. Rouelle has obſerved that cauſtic fixed alkali diſſolves a conſiderable quantity of this ſubſtance.

Charcoal alſo exiſts in a very attenuated ſtate in ether, alcohol, gum, &c.

I have examined ſome of its effects on the reduction of metals, in theſe different forms, in which it probably exiſts combined with hydrogen, and alſo ſome of its effects in the ſolid form.

EXP. I. GOLD.

A ſmall bit of well burned charcoal was ſuſpended by a thread in a phial containing a diluted ſolution of nitro-muriate of gold in diſtilled water: ſome air bubbles ſoon appeared on the charcoal: and in about two hours reduced gold was evident on its lower ſurface, and increaſed gradually, till the charcoal was nearly coated with gold of its proper colour.

This experiment was repeated with a richer ſolution of gold; the reduction did not commence near ſo ſoon, nor was the quantity reduced ſo great, or brilliant, as in the preceding experiment.

EXP. 2. GOLD.

A ſmall bit of charcoal was ſuſpended in a ſolution of gold in ether: an efferveſcence immediately commenced, and continued for a conſiderable time: but the ſolution ſuffered no change of colour; nor was there a particle of the gold reduced.

I ſhould not be ſurpriſed, if the gold were reduced in this experiment, as charcoal contains a large quantity of water, which it powerfully attracts from the ſurrounding air: however not a veſtige of reduced gold could be perceived.

Bits of charcoal were ſuſpended in the ſame manner in moſt of the metallic ſolutions treated of in this eſſay: no change was perceived on thoſe immerſed in ſolutions of arſenic, manganeſe, and fuſed nitrate of ſilver in water: but a bit immerſed in a ſolution of the ſame nitrate in alcohol, had parts of it covered with bright ſparkling particles, which ſeemed to vegetate from the charcoal, and were evidently reduced ſilver: for they were not ſoluble in water, on the ſurface of which the bit of charcoal depoſited ſome ſmall ſpangles of great luſtre. The bits immerſed in ſolutions of ſulphate of iron and zinc exhibited ſome very faint ſigns of reduction.

But theſe experiments were not repeated, nor ſufficiently varied, to enable us to form a juſt opinion of the power of charcoal in reducing metals in this way.

A ſmall quantity of charcoal, reduced to fine powder, was digeſted ſeveral days in a ſtrong ſolution of cauſtic potaſh in alcohol; the phial was frequently ſhaken to promote the ſolution.

Some of the clear ſolution, which was of a reddiſh colour, was poured into a phial for uſe.

EXP. 3. GOLD.

A few drops of this ſolution of charcoal, or carbone, were applied to a bit of ſilk; after the alcohol evaporated, a ſolution of gold in ether was dropped on, and immediately produced a brown, which, in about half an hour, was changed to a purple hue, owing to water attracted from the air; but no other ſign of reduction appeared.

Another bit of ſilk was immerſed in the ſolution of carbone, and when the alcohol evaporated, a few drops of an aqueous ſolution

tion of gold were applied; a brown ſtain was inſtantly formed; the ſilk was kept wet with water; the ſtain gradually aſſumed a purple tinge, and, in about five minutes, ſome reduced gold of its proper ſplendour, and colour, appeared: and in ſome time after every part of the ſilk, to which the ſolutions of carbone and gold were applied, was coated with reduced gold, which remained permanent. During the experiment, it is neceſſary to keep the ſilk conſtantly wet with water.

If the ſolution of gold be applied before the alcohol evaporates, a black precipitate is formed, along with the brown ſtain. In an experiment made in this manner, a metallic film, whitiſh, and obſcure, appeared in the beginning; but ſoon vaniſhed: and in ſome time after the gold was reduced of its proper colour; and a ſpeck of ruby red appeared on the margin.

The ſilk viewed by tranſmitted light preſented various colours, as purple, blue, and ſome green.

EXP. 4. SILVER.

A few drops of the ſolution of carbone were applied to a bit of ſilk; when the alcohol evaporated, a ſolution of fuſed nitrate of ſilver in alcohol was applied: a light brown ſtain was immediately produced in the ſilk; but no reduced ſilver could be ſeen.

The ſolution of carbone was applied to another bit of ſilk, and when the alcohol evaporated, an aqueous ſolution of fuſed nitrate of ſilver was dropped on: a brown ſtain was inſtantly formed, and, in about ten minutes, minute films of reduced ſilver were viſible.

The ſilk was kept wet with water during the experiment; and the brown ſtain was gradually changed to black. In ſome little time the metallic films diſappeared.

If the ſolution of ſilver be applied to the ſilk, before the alcohol evaporates, black and brown precipitates are immediately formed; and commonly no reduced ſilver can be ſeen; but ſometimes very minute films appear.

EXP. 5. PLATINA.

To a bit of ſilk, which was immerſed in a ſolution of nitro-muriate of platina in diſtilled water, and dried in the air, a few drops of the ſolution of carbone were applied; but no viſible change was produced.

Another bit of ſilk was dipped in the ſolution of carbone, and when the alcohol evaporated, a few drops of the ſolution of platina were applied: a yellow precipitate was immediately formed, and, in about ten minutes delicate films of reduced platina were viſible: theſe metallic films ſoon vaniſhed; and nothing but a yellow ſtain and the precipitate remained.

A bit of calico, on which this experiment was repeated, transferred a bright film of reduced platina to the ſurface of water.

During the experiments, the ſilk and calico were kept wet with water.

EXP. 6. MERCURY.

On a bit of ſilk, which was immerſed in a ſolution of oxygenated muriate of mercury in diſtilled water, and dried in the air, a little of the ſolution of carbone was dropped; but the ſilk underwent no viſible change.

Another bit of ſilk was dipped in the ſolution of carbone, and, when the alcohol evaporated, a little of the ſame ſolution of mercury was applied; a yellow precipitate was immediately formed; and ſoon after ſmall films of reduced mercury appeared on the margin of the ſtain.

This experiment was repeated with a ſolution of nitrate of mercury, and the reduction of the metal was very evident on the margin of the ſtain, which was black: the precipitate on the bit of ſilk was of the colour of ſulphur.

EXP. 7. COPPER.

To a bit of calico, which was immerſed in a ſolution of acetite of copper in diſtilled water, and dried in the air, a few drops of the ſolution of carbone were applied; but no viſible change was produced.

On another bit of calico, which was dipped

ped in the ſame ſolution of copper, ſome of the ſolution of carbone was dropped: the calico acquired a ſlight tinge of brown; it was kept wet with water; and, in about twenty minutes, ſeveral white metallic films were evident.

A bit of ſilk, on which this experiment was made, acquired a beautiful red colour, ſimilar to the ruby red, with which copper tinges glaſs, and depending on the ſame cauſe, viz. the quantity of oxygen combined with the metal.

EXP. 8. LEAD.

A bit of white calico was immerſed in a ſolution of acetite of lead in diſtilled water, and dried in the air: then a few drops of the ſolution of carbone were applied; but no viſible alteration took place.

On another bit of the ſame calico, which was dipped in the ſolution of carbone, a little of the ſame ſolution of lead was dropped; and in a few ſeconds films of reduced lead, bright as ſilver, appeared: the calico was then immerged in water, and transferred a continuous pellicle of reduced lead to its ſurface.

This experiment was often repeated both on ſilk, and calico: ſometimes the lead is reduced in an inſtant; but at other times five or ſix ſeconds elapſe, before any reduced lead becomes viſible.

I alſo found, that a ſolution of potaſh in alcohol reduces lead; but not ſo ſoon, or effectually, or in ſuch quantity, as the former ſolution does; but it is evident, that theſe ſolutions differ only in the quantity of carbone, which they contain.

EXP. 9. TIN.

To a bit of calico, which was immerſed in a ſolution of muriate of tin in diſtilled water, and dried in the air, ſome of the ſolution of carbone was applied: but no ſigns of reduction appeared, nor was the colour of the calico much altered.

On another bit of calico, which was dipped in the ſolution of carbone, ſome of the ſame ſolution of tin was dropped: a white precipitate was inſtantly formed, attended with bright films of reduced tin: the calico was immerged in water; and left a bright metallic film on the ſurface of that fluid.

The ſame experiment ſucceeds on ſilk.

EXP. 10. BISMUTH.

A piece of ſilk, which was immerſed in a ſolution of nitrate of Biſmuth in diſtilled water, and dried in the air, ſuffered no viſible alteration, on applying the ſolution of carbone.

To a bit of calico, which was dipped in the ſolution of carbone, a few drops of the ſame ſolution of biſmuth were applied; and immediately ſilms of reduced biſmuth were evident. The calico was immerged in water, and transferred a bright metallic film to its ſurface.

This experiment ſucceeded alſo on ſilk.

Exp. 11. Arsenic.

A bit of ſilk was immerſed in a ſolution of muriate of arſenic in diſtilled water, and dried in the air, then a little of the ſolution of carbone was dropped on the ſilk; but no viſible alteration took place.

Another bit of ſilk was dipped in the ſolution of carbone, and when the alcohol evaporated, ſome drops of the ſame ſolution of arſenic were applied; and in a ſhort time a few minute metallic films were viſible on the ſilk, which, when transferred to water, were ſtill more ſo.

Tartarite of antimony, treated in the ſame manner, transferred a very delicate film, ſcarcely viſible, to the ſurface of water.

Exp. 12. Iron.

A bit of calico, which was dipped in a largely diluted ſolution of ſulphate of iron, and dried in the air, ſuffered no perceptible change, on applying the ſolution of carbone, except a ſlight tinge of brown.

Another bit of calico was immerſed in the ſame ſolution of iron, and placed on a bit of deal board, a few drops of the ſolution of carbone were then applied: the calico was kept conſtantly wet with water, and in about fifteen minutes films of reduced iron were viſible: the calico was immerſed in water, and left a bright metallic film on its ſurface.

EXP. 13. ZINC.

To a bit of ſilk, which was dipped in a largely diluted ſolution of muriate of zinc, and dried in the air, a few drops of the ſolution of carbone were applied; but ſcarce any alteration of colour, or other viſible change, occurred.

A piece of calico was immerſed in the ſame ſolution of zinc, and placed on a bit of thin deal board, a few drops of the ſolution of carbone were then applied: the calico was kept conſtantly wet with water; and in about fifteen minutes films of reduced zinc were evident: the calico was immerged in water, and transferred a very bright metallic film of the colour of zinc to its ſurface.

I alſo reduced muriate of cobalt in this manner.

EXP. 14. MANGANESE.

To a bit of ſilk, which was dipped in a diluted ſolution of nitrate of manganeſe, and dried in the air, ſome drops of the ſolution of carbone were applied; but nothing appeared, except a brown ſtain.

Another bit of ſilk was immerſed in the

ſolution of carbone, when the alcohol evaporated, a few drops of the ſame ſolution of manganeſe were applied: a brown ſtain was ſoon produced; the ſilk was kept wet with water, and in about twenty minutes films of reduced manganeſe of a bluiſh white colour were evident on the ſilk.

This experiment did not ſucceed with a ſtrong ſolution of nitrate of manganeſe.

The ſame experiment ſucceeds alſo on linen, and calico, both with nitrate, and ſulphate of manganeſe; the reduction is attended with violet, and purple, colours, ſuch as this metal imparts to glaſs, and other ſubſtances, in which it exiſts combined with different proportions of oxygen: this difference is the cauſe of the different colours, which ſolutions of manganeſe aſſume.

The bright films of reduced manganeſe ſoon diſappear, the cauſe of which has been explained in the firſt chapter of this eſſay: the explanation there offered is confirmed by the following facts.

“ Regulus of Manganeſe,” ſays Mr. Bergman, “ when well fuſed generally perſiſts in
“ a dry place, but ſometimes undergoes
“ ſpontaneous calcination, and falls down in
“ a browniſh black powder.”

“ Moiſture, but particularly the acceſs of
“ aerial acid, aſſiſts this operation. A ſmall
“ piece, put into a dry bottle, well corked,
“ remained perfect for the ſpace of ſix
“ months, but afterwards, expoſed to the

" open air of a chamber for two days, con-
" tracted a browneſs on its ſurface, together
" with ſo much friability as to crumble be-
" tween the fingers. The internal parts,
" however, retained an obſcure metallic
" ſplendour, which diſappeared in a few
" hours*."

I ſhall now relate a few experiments made with ether, alcohol, and gum.

EXP. 15. GOLD.

I evaporated a ſolution of gold in nitro-muriatic acid to dryneſs, and diſſolved the ſalt in pure alcohol: the ſolution was poured into a phial carefully dried in hot ſand, and rinced with pure alcohol: the ſolution filled about $\frac{3}{4}$ of the phial, which was carefully corked, and though it was nine months expoſed to the gray light, no films of reduced gold appeared.

Part of the ſame ſolution was poured into a phial, and diluted with water; films of reduced gold ſoon appeared.

EXP. 16. GOLD.

A phial half filled with a ſolution of gold in ſulphuric ether was expoſed nine months to the gray light; but no films of reduced gold were produced.

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* Chem. Eſſay. Vol. II. p. 206 and 207. Eng. Tranſ.

On a bit of ſilk, which was dipped in part of the ſame ſolution of gold, and expoſed to the gray light, and kept wet with water, reduced gold appeared in the ſpace of a few hours.

Exp. 17. Gold.

I mixed an aqueous ſolution of gold with a ſolution of gum arabic in diſtilled water, in ſuch proportion, as to prevent the ſolution from ſpreading in the ſilk.

With this ſolution I drew ſeveral ſtripes on a piece of ſilk, and expoſed it to the gray light of a chambre: in ſome time the gold was reduced attended with blue, and purple, colours.

Similar ſtripes were drawn on another piece of ſilk, which, after the ſtripes became ſufficiently dry, was placed over the vapour of hot water; and in about fifteen minutes the gold was reduced in a beautiful manner.

This ſolution was applied to another bit of ſilk, which, after it became ſufficiently dry, was placed between the leaves of a blank book, to exclude the action of light; the gold, after ſome time, was reduced.

I found that ſmall ſtripes, and ſpots, made with this ſolution, were reduced by breathing on them for ſome time.

Sugar alſo, mixed with the ſolution of gold, promotes the reduction; but not ſo well as gum.

A bit of ſilk was dipped in a ſolution of nitrate of ſilver in diſtilled water, and expoſed, while wet, to the ſmoke of a common fire; in a ſhort time reduced ſilver appeared.

The following inferences are deducible from the experiments related in this chapter.

1. Charcoal is capable of reducing the metals in the ordinary temperature of the atmoſphere.

2. Water is eſſential to the reduction of metals by charcoal: for theſe experiments prove, that the reduction cannot be effected without water.

3. Charcoal does not reduce the metals by giving them phlogiſton; or by uniting with, and ſeparating, their oxygen; for were either of theſe opinions true, metallic ſolutions in ether, and alcohol, ſhould be as effectually reduced by charcoal, as metallic ſolutions in water are.

4. Ether, and alcohol do not promote the reduction of metals without the aid of water: but when this is preſent in ſufficient quantity, they effect the reduction, in the ſame manner, that charcoal, and other combuſtible bodies do.

It is evident then that charcoal reduces the metals by decompoſing water; which ſeems to be effected in the following manner.

The carbone of the charcoal attracts the oxygen of the water, while the hydrogen of the latter unites, in its naſcent ſtate, with the oxygen of the metal, and reduces it.

Hence it follows that the carbone is oxygenated by the oxygen of the water, and forms carbonic acid, while the metal is reſtored to its combuſtible ſtate.

This explanation is ſupported by the following fact: M. Gengembre has obſerved, that if charcoal be immerſed in water, and kept at a temperature of 30 degrees of the thermometer of M. De Reaumur, the water is gradually decompoſed, and inflammable gas is formed*.

That charcoal effects the reduction of metals, in high degrees of heat alſo, by decompoſing water, is evident from the following obſervations.

The great force with which charcoal attracts water is a fact ſufficiently eſtabliſhed; Dr. Prieſtley is ſo convinced of this, that he expreſſes himſelf in the following ſtrong terms. "I did not know, nor could believe "the powerful attraction, that charcoal, or "iron, appear to have for water; when they "are intenſely heated, they will find, and "attract it in the midſt of the hotteſt fire "through any pores in the retort †."

Now ſince water is eſſential to the reduction of metals in low degrees of heat; and ſince that fluid is always preſent, when metals are reduced by charcoal in high degrees of heat; it is manifeſt, that charcoal acts in the ſame manner in both theſe temperatures; and ſince water is eaſily, and inſtantly, decompoſed by charcoal at a red heat, as the Antiphlogiſtians themſelves allow; it clearly follows that their theory of metallic reduction is erroneous: for ſince the water is inſtantly decompoſed by the charcoal, it is a neceſſary conſequence, that its carbone muſt unite with the oxygen of the water, while the hydrogen of the latter unites, in its naſcent ſtate, with the oxygen of the metal, and reduces it, forming a new quantity of water equal to that decompoſed: this new quantity of water may be decompoſed in its turn: ſo that a thimble full of water would be ſufficient to reduce any quantity of metal; provided the water were prevented from eſcaping, and time enough allowed.

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* Eſſay on Phlogiſton, new Ed. by M. Kirwan, p. 61.

† Phil. Tranſ. 1785. Vol. LXXV. p. 289.

Beſide this ſource of water, the air of the atmoſphere, which contributes to ſupport the fire is an inexhauſtible magazine of water: and the hotter the air is, the more water it holds in ſolution; as M. Le Roy has demonſtrated [*]. Moreover all metallic oxids and ores contain a large proportion of water.

From this view it appears, that the manner, in which charcoal, and other combuſtible bodies, effect the reduction of metals, is by aſſiſting to decompoſe water, the hydrogen of which is therefore the only reducer of the metals.

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[*] El. Nat. Hiſt. & Chem. Eng. Tranſ. in three volumes, p. 163. Vol. I.

In order to point out the difference between this opinion, and that of the Antiphlogiſtians, I ſhall preſent the reader with M. Lavoiſier's idea of metallic reduction.

" It can not be doubted," ſays that celebrated chymiſt, " that charcoal at a red heat " takes oxygen from all metallic ſubſtances: " this is a fact againſt which no exception " can be made: and it is the foundation of " the whole theory of metallic reduction."

But the experiments in this eſſay demonſtrate, that this aſſertion is erroneous in every inſtance of metallic reduction: for ſo far is it from being true, that charcoal takes oxygen from all metallic ſubſtances, that it never does ſo in one ſingle inſtance; ſince its carbone always unites with the oxygen of the water, the hydrogen of which unites immediately to the oxygen of the metal, and reduces it.

" But this action of charcoal on oxygen," adds M. Lavoiſier, " this property, which it " poſſeſſes of taking it from metallic ſub- " ſubſtances, is not ſo ſtrong in the cold, as " at a red heat, ſince we are unacquainted " with any metallic revivification effected by " charcoal without heat *."

It is evident that this mode of reaſoning is no longer of any weight; ſince charcoal does

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* Eſſ. on Phlog. a new Ed. by M. Kirwan, p. 60.

reduce metals in the ordinary temperature of the atmoſphere.

The reaſon charcoal is more powerful in high degrees of heat, than other reducers of the metals, is its great fixity in the fire, and the immenſe force, with which it attracts, and impriſons water in its pores: thus preventing its eſcape till it be decompoſed by an affinity, which is much more complex than has been hitherto imagined.

Another reaſon of the ſuperior power of charcoal in metallic reduction is, that it forms a volatile elaſtic fluid with the oxygen of the water, which flies off; and conſequently does not react on the metal, or diſturb, or impede, by its preſence, the action of the reducing powers: advantages that phoſphorus, or any other combuſtible ſubſtance, which forms a fixed acid, that reacts on the metal, can never poſſeſs.

CHAPTER VIII.

REDUCTION OF METALS

BY

LIGHT.

THE next ſubſtance, I ſhall treat of, is Light, which ſeems well adapted to illuſtrate the theory of metallic reduction; as in experiments made with this ſubſtance, water can be more effectually excluded, than in trials with any other reducer of the metals.

Before any deciſive experiments could be made on light, or indeed any other reducer of the metals, it is obvious that we ſhould firſt aſcertain the effects of water itſelf in the ordinary temperature of the atmoſphere: to determine this point, the two following experiments were made.

EXP. 1. GOLD.

A piece of ſilk was immerſed in an aqueous ſolution of nitro-muriate of gold, and ſuſpended in a phial over water: the phial was corked, covered with black ſilk, and placed in a dark cloſet, to prevent the action of light. The experiment was continued from the 20th of July to the 20th of October, during which time the ſilk was frequently obſerved, and found to continue moiſt: but no alteration could be perceived, except that the yellow colour, which the ſolution of gold gave the ſilk, was changed to a light brown.

The ſilk was now taken out of the phial, and a ſolution of phoſphorus in ether applied to it: ſhortly after, a white metallic film appeared: the ſilk was then kept wet with water, and in ſome time, reduced gold of its proper colour appeared.

EXP. 2. SILVER.

A bit of ſilk, which was dipped in an aqueous ſolution of nitrate of ſilver, was ſuſpended in a phial over water, and placed in a dark cloſet, from the 20th of July to the 20th of October, and examined from time to time; but no alteration could be obſerved; its white colour continued pure, and unchanged.

The ſilk was now taken out of the phial, and the ſilver was immediately reduced by means of a ſolution of phoſphorus in ether.

Hence it appears, that water alone has not the power of reducing metals in the ordinary temperature of the atmoſphere.

EXP. 3. GOLD.

On the 24th of July a piece of ſilk was immerſed in a ſolution of nitro-muriate of gold in water, and dried by a gentle heat; it was then ſuſpended in a window, expoſed to the ſunbeams, as much as poſſible: no change was perceived on it, till the 26th, when the margin of the ſilk began to aſſume a purple tinge, which increaſed gradually, and on the 29th exhibited a few obſcure ſpecks of reduced gold on the ſide of the ſilk oppoſed to the light.

The purple tinge continued to increaſe, and the yellow, which the ſolution of gold gave the ſilk, decreaſed gradually, till on the 27th of Auguſt the colour was a mixture of purple, and light brown.

The reduction of the gold ſeemed to keep pace with theſe changes of colour, and was very evident on ſome parts of the ſilk even in the gray light; but much more ſo in ſunſhine: theſe changes were obſerved till the 20th of October; the experiment was then diſcontinued; and ſcarce any reduced gold could be ſeen on the ſide of the ſilk not oppoſed to the light.

That this ſlight reduction of the gold, and changes of colour in the ſilk, depended on water abſorbed from the air of the chambre, will appear from the following experiments.

EXP. 4. GOLD.

A bit of ſilk, which was dipped in the ſolution of gold employed in the preceding experiment, was dried, and ſuſpended in a cryſtal phial over dry carbonate of potaſh:

the phial was then corked, and further ſecured from external humidity by covering the cork with wax: it was now placed in a dark cloſet 24 hours, that the carbonate of potaſh might have ſufficient time to attract all the moiſture, it could, from the air of the phial, before expoſing it to the action of light.

The phial was then placed in a window, expoſed, as much as poſſible, to the ſolar light, from the 24th of July to the 20th of October, and carefully obſerved: the ſame ſide of the ſilk was always oppoſed to the light, and had the yellow tinge, which the ſolution of gold gave, altered to a browniſh yellow: but the other ſide of the ſilk ſuffered no viſible change whatever; nor could any purple tint, or the ſmalleſt veſtige of reduced gold be perceived.

Another bit of ſilk, which was immerſed in the ſame ſolution of gold, and dried by a gentle heat, was ſuſpended over ſome dry carbonate of potaſh, contained in a cryſtal phial covered with black ſilk, and placed in a dark cloſet, during the ſame ſpace of time, underwent no viſible change whatever.

Both theſe bits of ſilk were now taken out of the phials, and the gold was inſtantly reſtored to its metallic ſplendour by means of water and a ſolution of phoſphorus in ether: a proof that the nitro-muriate of gold, in theſe bits of ſilk, ſuffered no change, during that ſpace of time.

Exp. 5. GOLD.

A piece of ſilk, which was dipped in the ſame ſolution of gold, and placed on a china plate expoſed to the ſunbeams, was kept moderately wet with water during the experiment: the firſt alteration obſerved was, that the yellow colour of the ſilk began to change to a faint green, ſucceeded by a purple tinge, which in about fifteen minutes exhibited ſome particles of reduced gold: ſoon after the threads of the ſilk, which acquired this purple tint, were gilded with gold; and, in about an hour, the whole of the ſilk was covered with a ſuperb coat of reduced gold, exhibiting the texture of the ſilk in a beautiful manner.

The purple tinge, which attended the reduction verged in ſome parts on red, and in others on blue.

This experiment, which is very amuſing, I have repeated times unnumbered: and when the ſun is powerful, and the ſolution of gold properly prepared, and of due ſtrength. the coat of reduced gold is ſo bright, and dazzling, as to diſtreſs the eye of the beholder.

I find, that the beſt way of preparing a ſolution of gold for this purpoſe is to ſeparate the oxid of gold from its ſolution in nitro-muriatic acid by means of good ether.

The ſilk may be dipped in this ſolution, and when the ether evaporates, kept moderately wet with diſtilled water.

It was with this ſolution in ether that I firſt reduced gold in the fibres of ſilk, and it was by means of the ſame, I diſcovered, that water was a neceſſary condition in theſe reductions by light.

EXP. 6. GOLD.

A bit of ſilk, which was dipped in a ſolution of nitro-muriate of gold in alcohol, and placed on a china ſaucer, expoſed to the ſunbeams, was kept wet with alcohol for the ſpace of an hour; but no change even in the colour, which the ſolution of gold gave the ſilk, could be perceived.

The alcohol diffuſed the ſolution of gold unequally through the ſilk: the rays of the ſun being intercepted, ſuſpended the experiment: there was no ſunſhine on the following day: on the third day the ſilk was again expoſed to the ſunbeams, and kept wet with alcohol, which extracted a yellow tincture; a proof that the gold in the ſilk ſuffered no degree of reduction: the ſun ſhone pretty ſtrong for an hour, or more; and, at length, a faint tinge of purple, followed by ſome reduced gold, appeared.

The preceding experiments leave us no room to doubt, that the purple tinge and the ſmall quantity of reduced gold, that appeared in this experiment, depended on water attracted from the air, or depoſited in the ſilk by the alcohol during its evaporation.

Mr. Scheele reduced a ſolution of nitro-muriate of gold in water by expoſing it in a phial for a fortnight to the rays of the ſun *.

Mr. Lewis alſo made many experiments on the ſtaining of marble, and other ſubſtances with metallic ſolutions, and light †.

EXP. 7. SILVER.

A piece of ſilk, which was immerſed in a ſolution of nitrate of ſilver in water, was dried by a gentle heat, and expoſed to the light of the ſun as much as poſſible in the window of a chambre from the 20th of July to the 20th of October.

In leſs than an hour the ſilk acquired a reddiſh brown colour: next day the colour became more intenſe, and gradually increaſed, till, on the third day, it bordered on black, which increaſed ſlowly: at length part of it became gray, and a few minute particles of reduced ſilver could be diſtinguiſhed: the black tinge gradually diſappeared, and the ſilk was of a reddiſh brown colour: the reduced ſilver had a gray caſt.

The following experiments demonſtrate, that the changes of colour, and the few particles of ſemireduced ſilver depended on water attracted from the atmoſphere.

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* Experiments on Air and Fire, Eng. Tranſ. p. 82.

† Commerce of the Arts.

EXP. 8. SILVER.

A bit of ſilk was immerſed in part of the ſame ſolution of nitrate of ſilver in water, and dried in the dark: the ſilk retained its white colour: it was then ſuſpended over dry carbonate of potaſh in a cryſtal phial, which was corked, and ſecured from the ingreſs of moiſture by covering the cork with wax.

The phial was left in a dark cloſet 24 hours, that the ſalt might imbibe as much moiſture as poſſible from the ſilk, and air.

The phial was then placed in a window, expoſed, as much as poſſible, to the rays of the ſun, from the 24th of July to the 20th of October: the ſilk ſcarcely ſuffered any viſible change, except a very faint tinge of reddiſh brown; which was beſt ſeen by tranſmitted light; for the ſilk viewed by reflected light appeared nearly white: but that even this tinge, ſlight as it was, depended on a minute quantity of moiſture, which the carbonate of potaſh was unable to extract, appears from the next experiment.

EXP. 9. SILVER.

A piece of ſilk was dipped in a ſolution of fuſed nitrate of ſilver in alcohol, and carefully dried: it was then ſuſpended over a quantity of concentrated ſulphuric acid in a cryſtal phial, which was coated with a double fold of black paper, and gum arabic, reaching ſomewhat above the level of the acid, to prevent the light from acting on it: the phial was corked, and to exclude moiſture more effectually, the cork was covered with wax.

The phial was now placed in a dark cloſet 24 hours, that the humidity of the encloſed ſilk and air might be attracted by the acid: it was then placed in a window, expoſed as much as poſſible to the rays of the ſun, from the 19th of July to the 26th of October: but the ſilk underwent no viſible change whatever: its white colour remained pure, and unaltered.

The ſilk, at the end of this period, was taken out of the phial, and wetted with water: a ſolution of phoſphorus in ether was then applied to it; and inſtantly the metallic ſplendour of the ſilver appeared.

Another bit of ſilk, which was immerſed in a ſolution of nitrate of ſilver in water, and dried in the dark, was ſuſpended over dry carbonate of potaſh in a phial, and placed in a dark cloſet about two months: the ſilk underwent no viſible alteration whatever: its white colour remained pure.

I was deſirous of knowing, if the nitrate of ſilver in this bit of ſilk ſuffered any change, that might render it incapable of reduction: I therefore took it out of the phial, and divided it into two parts: one of theſe was wetted with water, and the ſilver was inſtantly reduced by a ſolution of phoſphorus in ether. The other part, which was ſuſpended in a window, expoſed to the air of the chamber, and rays of the ſun, ſoon acquired a reddiſh brown colour.

Hence it is evident, that theſe changes of colour indicate partial reductions of the metal; and that they never happen without the preſence of water.

EXP. 10. SILVER.

A bit of ſilk, which was dipped in a ſolution of nitrate of ſilver in water, was placed on a China ſaucer, expoſed to the rays of the ſun, and kept moderately wet with water: in a few minutes the white colour of the ſilk was changed to a reddiſh brown, which by degrees became darker; and, in about three or four hours, though the ſolar rays were often languid, and intercepted, acquired a blackiſh gray colour, moſt of the reddiſh brown having diſappeared: next day there was no ſunſhine; but towards the evening particles of reduced ſilver were viſible on the ſide of the ſilk oppoſed to the light.

EXP. 11. SILVER.

A bit of ſilk, which was immerſed in a ſolution of nitrate of ſilver in alcohol, and expoſed to the beams of the ſun, as in the preceding experiment, was kept moderately wet with alcohol; but reſiſted the action of the light much longer than the preceding: however, in ſome time, ſpecks, and lines, of a reddiſh brown, began to appear on ſome parts of the ſilk: next day, though there was no ſunſhine, the reddiſh brown colour increaſed a little: on the third day, it became more intenſe; but no black, or gray colour, or particle of reduced ſilver, could be obſerved.

Whoever compares this with the preceding experiments, can have no doubt that the changes of colour, which appeared in this experiment, depended on water attracted from the air, or depoſited in the ſilk by the alcohol during its evaporation.

The experiments detailed in this Chapter, prove beyond the power of contradiction,

1. That water is eſſential to the reduction of metals by light: for theſe experiments demonſtrate, that the reduction can not take place without water, and that it is always in proportion to the quantity of that fluid preſent.

2. That light does not reduce metals by giving them phlogiſton, as Meſſrs. Macquer and Scheele ſuppoſed; for were this opinion true, light ſhould reduce them without the aid of water, and as well with alcohol as with water.

3. Light does not reduce metals by fuſing and expelling their oxygen, as the antiphlogiſtians imagine; for were this its mode of agency, the reduction ſhould happen without the aſſiſtance of water, and as well with alcohol as with water.

4. Light is a combuſtible body; for it acts

like hydrogen, phoſphorus, ſulphur, and charcoal, in the reduction of metals.

Since water then is eſſential to the reduction of metals by light, and ſince light does not reduce metals by giving them phlogiſton, nor by fuſing, and expelling their oxygen, it follows, that the water is either decompoſed, or that it unites with metallic earths, and conſtitutes their phlogiſton, or that it unites with, and ſeparates their oxygenous principle: but as the two laſt ſuppoſitions are inadmiſſible, it is obvious that light reduces the metals by decompoſing water.

After explaining the manner in which other combuſtible bodies reduce the metals by decompoſing water; it will not be difficult to explain how light too produces the ſame effect.

But in order to facilitate the explanation, it muſt be premiſed,

1. That it is a law of attraction, that, when any body is deprived, to a certain degree, of another, for which it has a ſtrong affinity, the attraction of the former for the latter is much increaſed.

2. That light has a ſtrong attraction for oxygen, or the baſe of vital air.

3. That when oxygen is condenſed, and fixed in any ſubſtance, it contains much leſs light, and caloric, than it does in the gazeous ſtate.

4. That the oxygenous principle exiſts in

water in this condenſed ſtate, and conſequently has a ſtrong attraction for light.

Therefore, when light reduces the metals, it attracts the oxygen of the water, while the hydrogen of the latter unites, in its naſcent ſtate, to the oxygen of the metal, and reduces it, forming at the ſame time a quantity of water equal to that decompoſed.

Hence it follows that the light is oxygenated, and changed into vital air, while the metal is reſtored to its combuſtible ſtate.

CHAPTER IX.

REDUCTION OF METALS

BY

ACIDS.

IT is well known that ſolutions of gold throw up films of the reduced metal to the ſurface of the fluid, and ſides of the phials that contain them.

It has been ſhown, chap. 7th, that this effect depends on the preſence of water, which is further illuſtrated by the following experiments.

EXP. I. SILVER.

A dram of ſaturated ſolution of nitrate of ſilver in diſtilled water was mixed with half an ounce of vinegar, in a few minutes, a precipitate was formed: the whole was then poured on a filter, and waſhed with diſtilled water: the precipitate acquired a bluiſh gray metallic appearance: the liquor, which paſſed the filter, got a brown colour, and became blackiſh: next day bright films of reduced ſilver floated on the liquor; and in ſome months after, a conſiderable part of the inner ſurface of the phial was coated with reduced ſilver. Diſtilled vinegar did not produce this effect.

Exp. 2. Platina.

If a ſolution of the ore of platina in nitro-muriatic acid be evaporated to dryneſs; and the ſalt diſſolved in water, films of a livid white metallic appearance are thrown up to the ſurface.

Exp. 3. Tin.

Some tin, which was diſſolved in a china cup in muriatic acid, and evaporated to dryneſs, was diſſolved in diſtilled water; immediately white metallic films appeared on the ſurface of the liquor; and after ſome hours, the whole ſurface of the ſolution was covered with a continuous metallic pellicle, which reflected all the colours of the rainbow, in a beautiful manner.

Exp. 4. Mercury

Mr. Bergman ſays, "calcined mercury is "reduced by digeſtion in acid of ſalt; but "the cauſe has not yet been ſufficiently ex-"plored *."

As this reduction of mercury by muriatic acid is doubted of by ſome; I made the following experiment.

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* Elec. Attrac. Eng. Tran. p. 223.

A quantity of precipitate *per ſe* was put into a china cup, placed on hot ſand, and ſome muriatic acid was poured on it: the oxid was gradually diſſolved, and the digeſtion continued, till the acid was nearly evaporated: ſome diſtilled water was then poured on the ſalt, and minute films of a bright metallic appearance floated on the ſurface.

A nitrate of mercury was evaporated to dryneſs; the ſalt acquired a slight tinge of yellow; the cup was removed from the hot ſand, and ſome water poured on the ſalt: immediately bright films of reduced mercury appeared; and in about three or four hours the whole ſurface of the ſolution was covered with a metallic pellicle, parts of which had the colour and ſplendour of the metal; and other parts reflected a wonderful variety of the moſt beautiful colours.

EXP. 5. ARSENIC.

A quantity of white oxid of arſenic and muriatic acid was digeſted in the ſame manner in a china cup; a ſmart heat was continued, till moſt of the acid evaporated, and left behind a maſs of the conſiſtence of tar: the ſurface of which had a gray appearance; after it cooled, ſome diſtilled water was poured on, it diffuſed a diſagreeable ſmell, and films of reduced arſenic were thrown up to the ſurface; theſe were for ſome time remarkably bright, but ſoon became of a dull gray colour, owing to the rapid tendency of this metal to ſpontaneous calcination.

EXP. 6. MANGANESE.

Some concentrated ſulphuric acid was poured on a quantity of the black oxid of manganeſe in a china cup, placed on hot ſand: an efferveſcence was viſible, but no ſulphurous acid gas was exhaled: the cup was removed from the ſand, before any perceptible quantity of the acid evaporated: then ſome water was poured on the mixture: and inſtantly the ſurface of the fluid was covered with very brilliant metallic films: and, at the ſame time, the ſolution acquired a roſe colour.

Some of the ſame oxid of manganeſe was diſſolved in nitric acid, in which a bit of ſugar was put: the ſolution was poured into a china cup, placed on hot ſand, and, as the evaporation proceeded, bright metallic films appeared on the ſurface.

Mr. Bindheim of Moſcow relates, that he reduced the aërated calx of manganeſe diſſolved in nitrous acid: "the ſolution was "placed upon an open fire in a glaſs re"tort *."

Happening to pour out a very largely diluted ſolution of ſulphate of iron, I was ſurpriſed to find the flags of the court in an hour or two after, covered with large films

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* Crell's Chem. Jour. Vol. II. p. 48. Eng. Tranſ.

of a livid white metallic aſpect: theſe films, after the water evaporated, remained on the flags ſeveral days.

In conſequence of this I poured a largely diluted ſolution of ſulphate of iron into ſeveral ſhallow veſſels, and always found the ſurface of the ſolution covered with abundance of bright metallic films.

I alſo found that a largely diluted ſolution of muriate of zinc throws up bright metallic films to the ſurface.

The reduction of metals by acids is a very convincing proof of the decompoſition of water, and ſeems inexplicable on any other principle.

The reduction and calcination of metals by heat and electricity are naturally explained on the ſame principle: Doctor Prieſtley informs us in his Hiſtory of Electricity, Vol. I. p. 344, that S. Beccaria revived ſeveral of the metals by the electric ſhock. It is obvious that the electric fluid produces this effect in the ſame manner, that other combuſtible bodies do, viz. by decompoſing water. When the red oxid of mercury is reduced in cloſe veſſels by heat; the latter attracts the oxygen of the water, contained both in the oxid, and in the air of the veſſels, while the hydrogen of the water unites to the oxygen of the mercury, reduces it, and forms a quantity of water equal to that decompoſed.

It is found, that if light and caloric act both at the ſame time, the reduction is effected

with

with more facility, than if either acted ſeparately: in this caſe, the ſuperior efficacy of the combined action of light, and caloric reſembles that of other compound reducers of the metals; as that of ſulphurated hydrogen gas, phoſphorated hydrogen gas, alkaline ſulphure, &c. which are more powerful than ſimple hydrogen gas, ſulphur, or phoſphorus.

This ſuperior efficacy of compound reducers, is ſimilar to what happens with ſome other combinations of combuſtible bodies, as pyrites, pyrophori, a mixture of lead and tin, &c. which have a more powerful attraction for oxygen, than any of their ingredients, in a ſeparate ſtate.

Other acids, as the gallic, the tartarous, the formic, &c. and alſo alkalis, as ammonia, and ſoda, have the power of reducing ſome of the metals, facts well known to chymiſts.

CHAPTER X.

OXYGENATION
OF
COMBUSTIBLE BODIES.

IT has been ſhown, in the preceding chapters, that water is eſſential to the reduction of metals; that it is always decompoſed in that proceſs; and that the reducing ſubſtances are oxygenated by the oxygen of the water, while the hydrogen of the latter reduces the metals.

That water is alſo decompoſed in every inſtance of oxygenation, and that the oxygen of water alone oxygenates combuſtible bodies, will appear from the following obſervations.

AZOTE.

The firſt caſe of oxygenation, we ſhall conſider, is that of *azote*, in an experiment of Dr. Prieſtley, which has been urged by Mr. Kirwan with great ſucceſs againſt the Antiphlogiſtians.

"If the electric ſpark be taken in nitrous "air, it will be reduced to $\frac{1}{2}$ of its bulk, "and the reſiduum is mere phlogiſticated "air, and a little acid is depoſited. Now "the Antiphlogiſtians own that nitrous air "contains both pure air and phlogiſticated "air; ſince, therefore, this pure air diſappears, is it not evident that it was converted into water? and ſince the formation "of water requires the preſence of inflammable air, does it not follow that the nitrous air contained this alſo *?"

To this objection M. Berthollet replies, that the diminution of the nitrous gas "is "owing to the combination of the mercury "with the oxygene, which exiſted in the "gas †."

But this anſwer is inſufficient; as it does not account for the water, and acid, that appeared: and indeed, by this experiment, the Antiphlogiſtians are refuted on their own principles, and the decompoſition of water is inconteſtably proved; for as nitrous acid could not be formed without more oxygen than what exiſted in the nitrous air, is it not evident, that this oxygen muſt be derived from the water contained in the nitrous air? It is obvious then, that the water of the gas was decompoſed; which ſeems to have been effected in the following manner.

The electric ſpark diminiſhes the attraction of the conſtituent principles of the water for each other; hence the azote of the gas unites

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* Eſſay on Phlogiſton, new Ed. p. 82.

† Ibid. p. 122.

with the oxygen of the water, while the hydrogen of the latter combines with the oxygen of the gas; and thus water and nitrous acid are formed.

The formation of nitrous acid in Mr. Cavendiſh's noted experiment, cannot be explained on any other principle than the decompoſition of water: when the electric ſpark is taken in a mixture of azotic gas, and vital air; the water of theſe airs is decompoſed: the electric flame leſſens the force, with which the oxygen and hydrogen of the water adhere; hence the azote ſeizes the oxygen of the water, and forms nitrous acid, while the hydrogen of the water unites with the oxygen of the vital air, and forms a quantity of water equal to that decompoſed.

When nitrous, and vital air, are mixed; the whole maſs "hiſſes, turns red, grows warm, and contracts in bulk," the azote of the nitrous air attracts the oxygen of the water, and forms nitrous acid, while the hydrogen of the water unites in its naſcent ſtate with the oxygen of the vital air, and forms a quantity of water equal to that decompoſed.

Hence while the azote of the nitrous air is oxygenated; and the caloric is reſtored to its combuſtible ſtate.

"But it is to be obſerved," ſays M. Bergman, treating of this experiment, "that the "decompoſition of nitrous air is the effect "of a double attraction; the phlogiſton is

" attracted by the vital air, and the acid part
" by the water. Therefore, when the mix-
" ture is made in a phial immerſed in mer-
" cury, the experiment fails *."

HYDROGEN.

The combuſtion of hydrogen gas with vital air is explicable only on the decompoſition of the water contained in theſe airs: thus when flame, or a glowing body is applied to a mixture of them; the attraction of the principles of the water for each other is diminiſhed; therefore the hydrogen of the inflammable air unites with the oxygen of the water, while the hydrogen of the latter ſeizes the oxygen of the vital air: thus the whole bulk of the airs, which are changed into water, diſappears; and their light, and caloric, are reſtored to the combuſtible ſtate.

Hence it appears that water is not formed during the combuſtion of vital, and inflammable air, in the manner the Antiphlogiſtians ſuppoſe.

Indeed it is obvious, that, if theſe airs contained no water, they could never be burned: for ſince they are already ſaturated with light, and caloric, they can have no attraction for any additional quantity of theſe fluids; and conſequently can ſuffer no other change from the light, or caloric, of a glowing body, than

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* Elec. Attr. Eng. Tranſ. p. 211.

a greater degree of expanſion, and therefore could never unite.

The ſame reaſoning applies to the combuſtion of all elaſtic fluids.

PHOSPHORUS.

Vital air always contains a large proportion of water: when phoſphorus is burned in this air, it attracts the oxygen of the water, and forms phoſphoric acid, while the hydrogen of the water unites with the oxygen of the gas, and forms water, which unites with the acid.

Hence the weight of the acid formed is equal to the weights of the oxygen gas, and phoſphorus, conſumed; and the light and caloric, which appear during the combuſtion, are reſtored to their combuſtible ſtate.

This explanation is confirmed by an obſervation of Mr. Bergman, who ſays,

" In vital air, without the aid of external
" heat, phoſphorus is conſumed very ſlowly,
" and ſcarce at all, unleſs water be pre-
" ſent *."

Therefore the phoſphorus does not unite to the oxygen of the vital air, as M. Lavoiſier ſuppoſes, but to the oxygen of the water contained in the oxygen gas.

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* El. Att. Eng. Tranſ. p. 213.

SULPHUR.

When ſulphur is burned in vital air, it attracts the oxygen of the water, and forms ſulphuric acid, while the hydrogen of the water attracts the oxygen of the gas, and forms a quantity of water equal to that decompoſed: the light and caloric are at the ſame time reſtored to their combuſtible ſtate.

The ſulphur then does not unite with the oxygen of the vital air, as the Antiphlogiſtians imagine, but with the oxygen of the water contained in that gas.

CHARCOAL.

In like manner during the combuſtion of charcoal in vital air, the carbone attracts the oxygen of the water, and forms carbonic acid, while the hydrogen of the water unites with the oxygen of the vital air, and forms a new quantity of water equal to that decompoſed.

Hence the carbone of the charcoal does not unite with the oxygen of the vital air, as M. Lavoiſier ſuppoſes, but with the oxygen of the water contained in that gas.

That water is decompoſed in every inſtance of combuſtion, is further proved by attending to what paſſes during the burning of a common fire: the carbone of the fuel combines with the oxygen of the water, and forms carbonic acid, while the hydrogen of the water unites partly with the oxygen, and partly with the azote of the atmoſphere, and forms water, and the ammonia, which abounds in ſoot.

From theſe obſervations it is evident, that M. Lavoiſier's account of the formation of water, and acids, is erroneous, and inadequate to explain the phenomena.

The different kinds of fermentation are ſo many inſtances of the decompoſition of water: in every caſe of them, combuſtible bodies are oxygenated by the oxygen of the water, while others are reſtored by its hydrogen to their combuſtible ſtate.

Hence the azote, ammonia, and carbonic acid of fermentation, the inflammable air of marſhes, mines, &c. the azotic, and hydrogen gas, aſcending into the atmoſphere, and there meeting the vital air diſcharged from the water of plants, &c. form new quantities of air, and water.

When the azote is oxygenated, it unites with the oxygen of the water contained in the air, and forms atmoſpheric air, and ſometimes perhaps nitrous acid, the hydrogen of the water combines, at the ſame time, with the oxygen of the vital air, and forms a quantity of water equal to that decompoſed.

But when the hydrogen is oxygenated, a quantity of water double that decompoſed is regenerated; for the hydrogen of the gas unites with the oxygen of the water, while the hydrogen of the latter ſeizes the oxygen of the vital air: and thus a quantity of water double that decompoſed is formed, and that part of it which the atmoſphere cannot ſuſpend deſcends in the form of rain.

When theſe decompoſitions are rapid, the phenomena of thunder and lightning appear.

This account of the renovation of our atmoſphere explains why the phenomena of thunder and lightning appear ſometimes with, and ſometimes without rain, and alſo accounts for the production of the nitrous acid, which Mr. Margraaf diſcovered in the pureſt ſnow.

The breathing of fiſhes is a ſtriking proof of the decompoſition of water in reſpiration.

For this view of the formation of our atmoſphere I am indebted to a friend well acquainted with the experiments related in this eſſay, and alſo for the application of the opinion which I venture to advance, to the reſpiration of animals.

The phenomena of vegetation cannot be explained on any other principle, than the decompoſition of water by heat, and light, which uniting to the oxygen of the water contained in vegetables change it into ſtreams of vital air, that ſerve to renovate our atmoſphere: the hydrogen of the water, at the ſame time, contributes to form the oil and other principles of plants, and when theſe are decompoſed by the various proceſſes of combuſtion, forms a quantity of water equal to that conſumed in their formation.

The changes, which nitric acid ſuffers by expoſure to heat, or light, are explained with eaſe on this principle: the light unites with the oxygen of the water contained in the nitric acid, and forms vital air, while the hydrogen of the water combines with the oxygen of the acid, and forms a new quantity of water equal to that decompoſed: thus the nitric is converted into the ruddy nitrous acid.

METALS.

According to the Antiphlogiſtians, "In
" every metallic ſolution by an acid, the
" metal, in order to become oxided, decom-
" poſes either the acid itſelf, or the water of
" ſolution, or it obtains from the atmoſphere
" the requiſite quantity of oxygene. In the
" ſecond caſe, hydrogenous gas, in a ſtate
" of greater or leſs purity is diſengaged; and
" the acid remains entire without decompo-
" ſition, which is proved by the quantity of
" alkali neceſſary to ſaturate it. In the firſt
" caſe, one of the principles of the acid, or
" the acid deprived of part of its oxygene,
" is diſengaged, and fuſed in the caloric,
" which is ſeparated at the ſame time; ſuch
" are nitrous gas, and ſulphurous acid gas.
" In the third caſe, neither the water nor
" the acid are changed; ſuch is the ſolution
" of copper by the acetous acid.

" The muriatic acid, and the vegetable
" acids, which are formed of radicals, or
" acidifiable principles, which have more

" affinity with oxygene, than the metals " have, are not decompoſed by theſe metals, " and the oxygene is always afforded to theſe " laſt by the water or atmoſphere. Hence " the ſolutions by theſe acids afford only hy- " drogenous gas, or do not efferveſce at all.

" There are ſome caſes in which the wa- " ter and the acid are at the ſame time de- " compoſed by the metal, as in the ſolution " of tin in the nitric acid, according to the " obſervation of M. De Morveau."

" Tin is ſo greedy of oxygene, and requires " ſo large a quantity for its ſaturation, that " after having abſorbed that of the nitric " acid, and reduced it to the ſtate of azote, " it decompoſes likewiſe the water, and diſ- " engages hydrogene. Theſe two principles " being ſeparated from their firſt compounds, " unite together, and immediately form am- " moniac. Hence there is no diſengagement " of elaſtic fluid. In this caſe it appears, " that the formation of ammoniac, in the " ſolution of tin by the nitric acid, always " takes place; for by throwing quicklime, " or cauſtic fixed alkali, into this ſolution, " there is always a diſengagement of ammo- " niac *."

It is evident, then, that this account of the oxygenation of metals, given by the Antiphlogiſtians, is equally complex, as their ac-

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* Eſſay on Phlog. new Ed. by Mr. Kirwan, p. 233—235.

count of metallic reduction, and improbable; ſince every caſe, in which they deny the decompoſition of water, and derive the oxygen from other ſources, is eaſily, and naturally explained on that principle, as will appear from what follows.

Thus when mercury, or ſilver, is diſſolved in nitric acid; the metal attracts the oxygen of the water, while the hydrogen of the latter unites with, and ſeparates, more or leſs of the oxygen of the acid, which is thus changed into nitrous air.

The ſame thing happens during the ſolution of other metals in this acid; the only difference being the greater or leſs energy, and rapidity, with which they combine with the oxygen of the water.

This decompoſition of water is confirmed by the ſolution of tin in this acid; in which the Antiphlogiſtians allow the decompoſition of the acid, and the water too; for ammonia is formed by part of the hydrogen of the water, and azote of the acid.

In every caſe of metallic ſolution by ſulphuric, and muriatic acids, whether concentrated, or diluted, water is decompoſed: the metals attracting the oxygen of the water, while its hydrogen eſcapes in the form of inflammable air, or unites partly with the oxygen of the acid, and partly with caloric: hence the volatile ſulphurous acid, and muriatic acid air, obtained, always contain ſome hydrogen gas, as appears from the following obſervation of M. Bergman.

"By means of vitriolic acid, inflammable
"air is obtained from zinc, and iron, as alſo
"by means of marine acid; but, from the
"other metals diſſolved in vitriolic acid, we
"obtain another ſpecies of air, called *vitri-*
"*olic acid air*; and, by the marine acid, an-
"other ſimilar to the former, called *muriatic*
"*air*, but both more or leſs mixed with *in-*
"*flammable air*[*]."

Again, when copper is diſſolved in the acetous acid; the copper attracts the oxygen of the water, while the hydrogen of the latter unites with the oxygen of the atmoſphere, and forms water: hence no efferveſcence appears.

When alkalies diſſolve metals, the latter are always oxygenated at the expence of the water, which holds the alkali in ſolution: thus when lead, and copper, are diſſolved; the metals combine with the oxygen of the water, while its hydrogen unites to the oxygen of the atmoſphere, and forms water: hence no hydrogen gas appears.

The oxygenation of metals, and other ſubſtances by heat, and air, is eaſily explained on the ſame principle: the metals, &c. unite with the oxygen of the water contained in atmoſpheric air, while the hydrogen of the water combines with the oxygen of the air, and forms a quantity of water equal to that decompoſed.

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[*] Chem. Eſſ. Vol. II. p. 358. Eng. Tranſ.

This explanation is clearly proved by an experiment of Mr. Bergman on the regulus of manganeſe, which, if kept in a dry place, retains its metallic ſplendour; but, if expoſed to moiſture, is ſoon oxygenated, and loſes its luſtre *.

It is further confirmed by the authority of the diſtinguiſhed Mr. Scheele, who ſays, that "the water contained in common atmoſpheric air is the chief cauſe of the ignition of pyrophorus," which he proved by the following experiment.

"I made a very dry air by putting ſome very ſmall pieces of quicklime into a ſmall matraſs: then I put the neck of another matraſs into that of the firſt, ſo that the air of both might communicate; and I luted the crevices with wax. Two days afterwards I ſeparated the empty matraſs, and poured half an ounce of pyrophorus from my phial into it, and immediately carefully ſhut the aperture up: but I did not obſerve, that it grew in the leaſt warm: an hour after this, I put a ſponge moiſtened in water into the matraſs, and ſhut it up again: a few minutes after the pyropho-

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* Chem Eſſ. Vol. II. p. 206—207. Eng. Tranſ.

“ rus began ſtrongly to be heated, and ſome
“ pieces kindled ſpontaneouſly †.”

Many other facts might be adduced to prove, that oxygenation cannot take place without water, as the combuſtion of mixtures of iron filings, ſulphur and water, of alkaline ſulphure and water, &c. in which the water is decompoſed, and the combuſtible bodies oxygenated by its oxygen.

It is evident then from the experiments and obſervations related in this eſſay, that water is eſſential to the oxygenation of combuſtible bodies; and that it is the only ſource of the oxygen that oxygenates them: it is alſo evident, that when one body is oxygenated, another, at leaſt, is reſtored to the combuſtible ſtate: hence it appears that the oxygenation of combuſtible bodies is never effected by a ſingle affinity.

The Antiphlogiſtians treating of the precipitation of metals by each other, ſay,

“ Since the metals cannot remain united
“ to the acids, but in the ſtate of oxides of
“ a determinate degree, it is eaſily conceived,
“ that by plunging into a metalic ſolution a
“ metal which has a ſtronger affinity with
“ oxygene than that which is diſſolved, the
“ former muſt deprive the latter of its oxy-
“ gene, take its place in the acid, and cauſe
“ the ſecond to ſubſide in a form more or
“ leſs metallic, accordingly as it has deprived

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† Exper. on Air and Fire, Eng. Tranſ. p. 112, and 130.

"it of more or leſs oxygene. This is the "reaſon of the precipitation of ſilver by copper, copper by iron*," &c.

But this account of the precipitation of metals by one another cannot be admitted; for it has been proved in every inſtance of reduction related in this eſſay, that water is decompoſed, and that its hydrogen is the only ſubſtance that reſtores bodies to their combuſtible ſtate.

There is no reaſon then to ſuppoſe that nature deviates, in this particular caſe, from that uniform ſimplicity, which ſhe conſtantly obſerves in all her operations.

Therefore it is obvious, that, when one metal precipitates another in a form more or leſs metallic; the precipitant unites with the oxygen of the water, while the hydrogen of the latter combines with, and ſeparates, the oxygen of the precipitated metal, and thus reduces it.

The experiments made with phoſphorus and metallic ſolutions in ether, alcohol, and water, prove the truth of this explanation; and ſhow that when one metal precipitates another in the metallic form, it acts like a ſtick of phoſphorus, decompoſing the water.

This account of the reduction of one metal by another is ſupported by the opinion of Mr. Bergman, who ſays,

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[*] Eſſ. on Phlog. new Ed. by Mr. Kirwan, p. 236, and 237.

"It is well known, that the calx of copper, diſſolved in vitriolic acid, is precipitated in its metallic form on the addition of iron; and that by means of a double elective attraction; for the iron diſſolving in the acid would form an inflammable air by its phlogiſton, were not the copper preſent, which takes it up*."

The ſame author remarks, that a ſmall exceſs of acid is neceſſary, and that without it no precipitation begins.

Now ſince water is decompoſed by iron and ſulphuric acid, it muſt be allowed, that, when iron is immerſed in a ſolution of ſulphate of copper, the water is decompoſed by the iron and exceſs of acid, the iron attracting the oxygen of the water, while the hydrogen of the latter, unites to the oxygen of the copper, reduces it, and forms a quantity of water equal to that decompoſed.

The precipitation of ſilver in its metallic form by iron and other metals is to be explained in the ſame manner: and not by a ſingle affinity, as the Antiphlogiſtians imagine.

The reduction of gold, and ſome other metals, by ſolutions of ſulphate of iron, and muriate of tin, is readily accounted for on the principles advanced here; for freſh made ſolutions of ſulphate of iron, and muriate of tin, contain hydrogen, and have the power of decompoſing water: the oxygen of which unites with the iron, and tin, while its hydrogen ſeizes the oxygen of the gold, &c. reduces it, and forms a quantity of water equal to that decompoſed.

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* Chem. Eſſays, Vol. II. p. 384, Eng. Tranſ.

The decompoſition of water is further proved by the large dilution neceſſary to form the arbor Dianæ, the purple precipitate of Caſſius, and other inſtances of the reduction of metals by one another.

CHAPTER XI.

CONCLUSION.

I SHALL conclude with a general view of the inferences, which I ventured to advance in this eſſay.

1. Neither the Phlogiſtians, nor Anti-phlogiſtians, account in a ſatisfactory manner for the increaſe of weight, which bodies acquire during combuſtion.

2. Their account of the formation of water, acids, and oxids, is erroneous; for it has been ſhown that the oxygen of water alone oxygenates combuſtible bodies.

3. Combuſtible bodies, as hydrogen, phoſphorus, ſulphur, charcoal, light, &c. are capable of reducing the metals in the ordinary temperature of the atmoſphere; and indeed I might add, at a much lower temperature, as I frequently experienced.

4. Combuſtible bodies do not reduce the metals by giving them phlogiſton, as the Phlogiſtians ſuppoſe; nor by uniting with, and ſeparating their oxygen, as the Anti-phlogiſtians maintain.

5. Water is eſſential both to the reduction and oxygenation of bodies, and is always decompoſed in theſe operations.

6. Water does not contribute to metallic reduction merely by diſſolving and minutely dividing the particles of metallic ſalts, and thus removing the impediment oppoſed to chymical attraction by the attraction of coheſion: for were this the caſe, metallic ſolutions in ether and alcohol, in which that impediment is equally removed, ſhould be as readily and effectually reduced, as metallic ſolutions in water are.

This circumſtance, in which all the experiments on metallic reduction detailed in this eſſay exactly coincide, merits particular attention, and ſhows that the manner, in which combuſtible bodies effect the reduction, is the ſame in them all.

7. When one body is oxygenated, another, at leaſt, is reſtored at the ſame time to its combuſtible ſtate; and *v. v.* when one body is reſtored to its combuſtible ſtate, another at leaſt is at the ſame time oxygenated.

8. Quantities of air, and water, equal to thoſe decompoſed in the different ſpecies of combuſtion, are conſtantly a forming.

Thus nature, by maintaining this balance of power between combuſtible and oxygenated bodies, prevents the return of original chaos.

Since then in every act of combuſtion, one body, at leaſt, is oxygenated, and another reſtored, at the ſame time, to its combuſtible ſtate, the phenomena of combuſtion may be referred to two heads, viz.

Oxygenation, or the union of oxygen with combuſtible bodies, and

Reduction, or the reſtoration of oxygenated bodies to their combuſtible ſtate.

And ſince in every inſtance of combuſtion water is decompoſed, and one body oxygenated by the oxygen of the water, while another is reſtored to its combuſtible ſtate by the hydrogen of the ſame fluid, it follows,

1. That the hydrogen of water is the only ſubſtance, that reſtores bodies to their combuſtible ſtate.

2. That water is the only ſource of the oxygen, which oxygenates combuſtible bodies.

3. That no caſe of combuſtion is effected by a ſingle affinity.

This view of combuſtion may ſerve to ſhow how nature is always the ſame, and maintains her equilibrium by preſerving the ſame quantities of air and water on the ſurface of our globe: for as faſt as theſe are conſumed in the various proceſſes of combuſtion, equal quantities are formed, and riſe regenerated like the Phenix from her aſhes.

NOMENCLATURE *of the Chymical Terms uſed in this Eſſay.*

NEW NAMES.	OLD NAMES.
AMMONIA	CAUSTIC vol. alkali.
Acetite of lead	Sugar of lead.
——— copper	Verdirgris.
Azote	Baſe of phlogiſticated air.
Azotic gas	Phlogiſticated air.
Alkaline ſulphure	Liver of ſulphur.
Alcohol	Highly rectified ſpirit of wine.
Carbone	Pure coal.
Carbonic acid	Fixed air.
Caloric	Heat.
Hydrogen	Baſe of inflammable air.
Hydrogen gas	Inflammable air.
Hydrure of ſulphur	A compound of hydrogen and ſulphur.
——— phoſphorus	A compound of hydrogen and phoſphorus.
Muriate of tin	Salt of Jupiter.
——— ſilver	Luna cornea.
——— arſenic	Arſenic combined with muriatic acid.
——— zinc	Marine ſalt of zinc.
——— cobalt	Marine ſalt of cobalt.
Nitric acid	Dephlogiſticated nitrous acid.
Nitro-muriatic acid	Aqua regia.
Nitro-muriate of gold	A compound of gold and aqua regia.
——— platina	A compound of platina and aqua regia.

NEW NAMES.	OLD NAMES.
Nitrate of ſilver - -	Lunar nitre, cryſtals of the moon.
——— of mercury - -	Mercurial nitre.
——— of biſmuth - -	Nitre of biſmuth.
——— of mangaueſe -	Nitre of manganeſe.
Oxygen - - -	Baſe of vital air.
Oxygen gas - -	Vital air.
Oxygenated muriate of mercury - - -	Corroſive ſublimate.
Pruſſiate of mercury -	A compound of mercury and pruſſic acid.
Phoſphorated hydrogen gas	Phoſphoric air.
Potaſh - - -	Cauſtic vegetable alkali.
Sulphuric ether - -	Vitriolic ether.
Sulphureous acid gas -	Vol. ſulphureous acid.
Sulphurated hydrogen gas	Hepatic acid.
Sulphate of copper - -	Blue vitriol.
————zinc - -	White ditto.
————iron - -	Green ditto.
————manganeſe -	Vitriol of manganeſe.
Soda - - - -	Cauſtic mineral alkali.
Tartarite of antimony -	Emetic tartar.

FINIS.